New Scientist

WEEKLY February 13 - 19, 2016

GRAVITATIONAL WAVES
Found? The final piece of general relativity

ADDITIVE ALERT
The secret ingredient that makes you fat

BEAM ME DOWN
Power from the edge of space

RESURRECTION DOGS Inside South Korea's cloning factory

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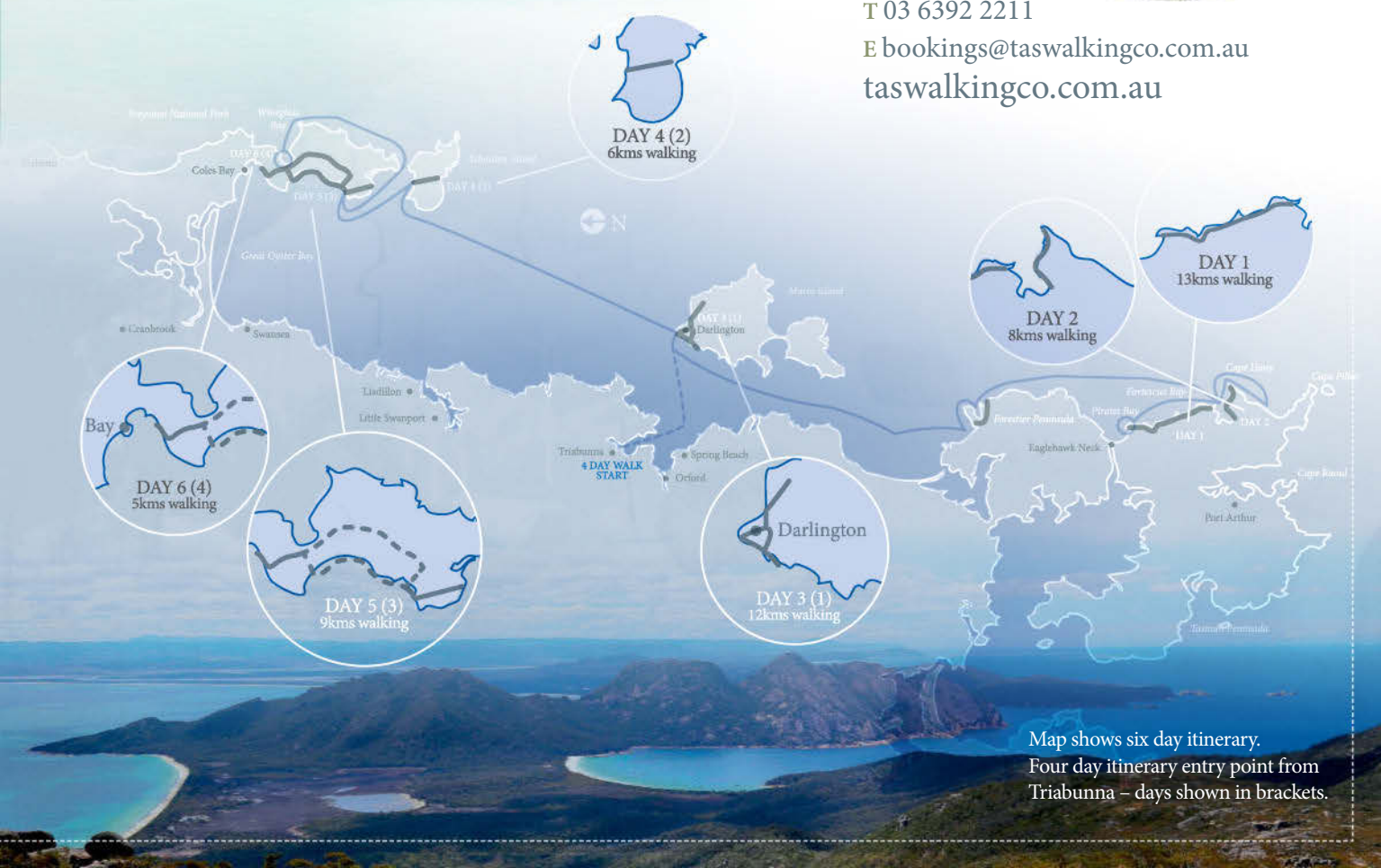

Map shows six day itinerary.
Four day itinerary entry point from Triabunna – days shown in brackets.

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Shooting for the moon

Can big money and big dreams make "impossible" projects happen?

ELEVATOR going up. Next stop: geostationary orbit! The notion of a tether extending from the ground to space is not new: it was first dreamed up by Konstantin Tsiolkovsky, the father of rocketry, all the way back in 1895.

The space elevator is an appealing concept. It also seems impossible. No material we know of comes close to being strong enough to support its own weight over tens of thousands of kilometres. So the idea has never attracted serious funding: the writer Arthur C. Clarke once said it would be built "about 50 years after everyone stops laughing".

They haven't stopped yet. But perhaps they should. Other implausible schemes are turning into engineering realities. Silicon Valley firms and entrepreneurs have started betting big on "moonshots": grand projects that will be tough, if not impossible, to pull off, but which would have a huge impact if they succeeded – like the Apollo space programme, the original moonshot.

Google's recent restructuring highlights this trend. The search firm is now just one of a family of enterprises targeting far-fetched objectives from driverless cars to longevity: its holding company Alphabet spent $3.74 billion on moonshots last year.

Is this money well spent? Debate has raged in business circles about whether Google's founders have the moral right to spend their investors' cash this way. Doubts may be assuaged by the promise of huge profits if any of these bets pay off. But what do the rest of us stand to gain?

Well, there's spectacle, for one thing. Elon Musk's first attempts to show off his reusable rocket left sceptics laughing. But then it started working – not perfectly,

"These grand projects would have a huge impact if they succeeded, like the Apollo space programme"

but well enough to silence the laughter. That gives space flight fans something to root for, at a time when many governments seem to have lost interest (the ambassadorial residents of the International Space Station notwithstanding).

The cost of this spectacle is not fronted by the public – not via taxation, anyway, although subsidies are a different matter. The expectation is that "new space" initiatives will mostly let the very rich work and play on the high frontier. But it could support the development of more public-spirited projects too.

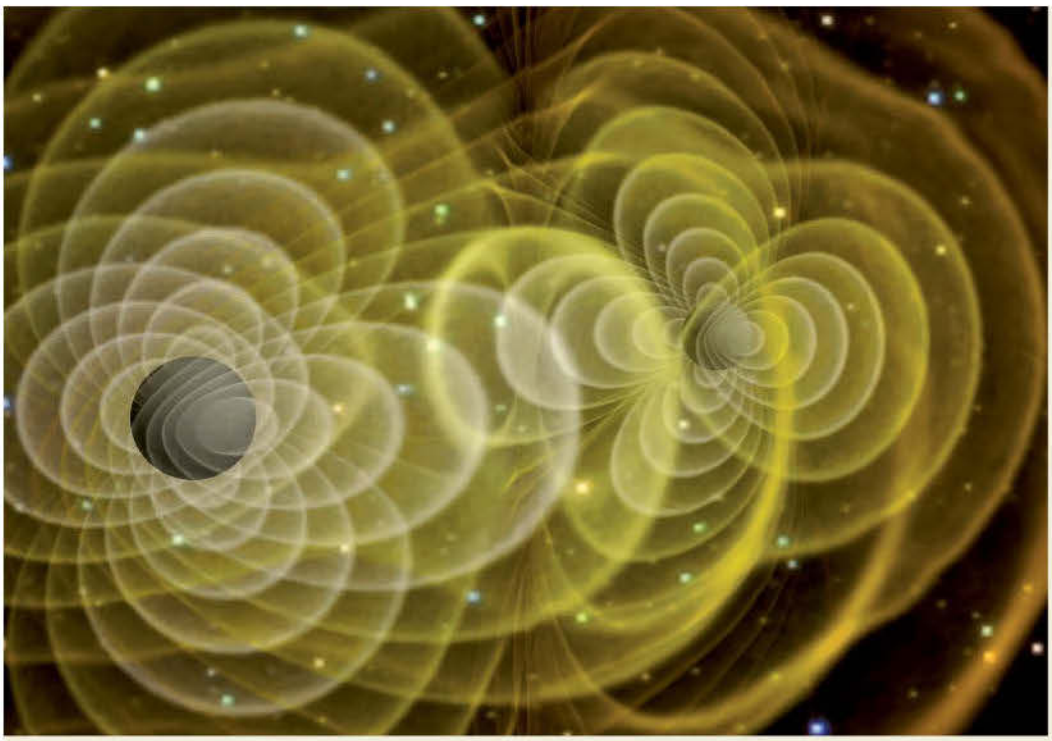
For example, orbiting solar power stations are another good idea that have always seemed laughably difficult in practice. The plan is simple: harness the sun's energy before it is dissipated by Earth's atmosphere, then beam it down using microwaves, thus providing clean, abundant energy.

The obvious objection is the astronomical cost of lifting huge amounts of equipment into space. Reductions in the weight of solar technology have encouraged stolid aerospace and utility firms to experiment in earnest (see page 38); perhaps the space flight moonshots can help them out.

Some may yearn for the days when the military-industrial complex led the way. But now politicians are following the Valley's rhetorical lead: last month, US vice-president Joe Biden proposed a billion-dollar moonshot to cure cancer, although he met with scepticism from some researchers.

We'll see if medicine eventually proves as receptive to moonshot thinking as engineering. Actually, we have yet to see if it can deliver a return on all those billions there, too. Let's hope it can: combining big money and big dreams might finally get some "impossible" ideas off the ground. Including, just maybe, a space elevator. ■

HENZE, NASA



Ripples of anticipation

NEVER mind the rumours. The most-sensitive ever search for gravitational waves seems to have glimpsed its quarry before it even started looking officially, *New Scientist* has found.

Gravitational waves are ripples in space-time predicted by Einstein's theory of general relativity. Massive objects like black holes and neutron stars warp space-time around themselves, and when two such behemoths collide, the distortions ripple outward at the speed of light. Although we are pretty confident this happens, no one had detected the waves themselves.

As *New Scientist* went to press, rumours were flying that the Laser Interferometer Gravitational-Wave Observatory (LIGO) team was about to announce just such a detection. The source was said to be the merger of two black holes, each about 30 times the mass of the sun.

The team has called a press conference for 11 February, but we already have reason to believe this is the real deal. By analysing public observation logs, *New Scientist* discovered that the team had followed up on at least three possible sources since it started listening to the sky last September.

LIGO's detectors, 3000 kilometres apart in Hanford, Washington, and Livingston, Louisiana, aim to spot passing gravitational waves by picking up stretches and contractions in space-time as small as one ten-thousandth the diameter of a proton.

The signal from the merger of two massive objects rises in frequency, then falls abruptly. Analysing it gives an idea of the event's distance and the masses of the bodies, but not where they are in the sky.

So the LIGO team asks astronomers at 75 observatories worldwide to scan for more traditional signals: visible light, gamma rays, even neutrinos. If a gravitational wave event is like the elusive Cheshire cat, then finding these counterparts is seeing the grin.

Although the results of these searches are not public, whether or not they have taken place is – and so are the coordinates. *New Scientist* focused on searches by the European Southern Observatory (ESO), a set of telescopes in Chile that can detect the flash of light that may accompany a gravitational wave signal.

"The first gravitational wave sighting could have fallen into LIGO's lap before it formally started looking"

We found that ESO began a search on 17 September, starting in the constellation Dorado and veering across other parts of the southern sky. LIGO's observing run officially began the very next morning, but the team had spent the previous few weeks collecting data in preparation.

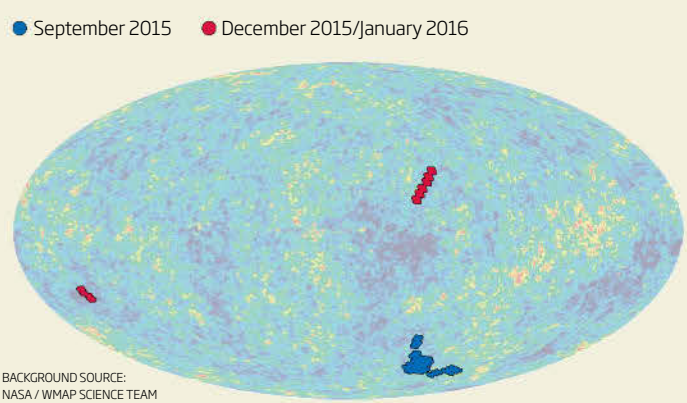
The first rumour of a signal appeared just a week later, to the consternation of team members. It seems the first sighting fell into LIGO's lap before the experiment formally started.

Two other ESO searches – one around the constellation Aries, the other in the rough vicinity of Hydra – both began on 28 December and continued until the end of the LIGO run on 14 January. Taken together, the three searches suggest LIGO has been unbelievably lucky.

The LIGO team is known to create false signals to test its analysis. In 2010, before LIGO was upgraded to its present sensitivity, an apparent signal turned out to be one of these deliberate fakes.

This time, given the team's scheme for introducing fakes, it's likely that at least one of the signals is real. Joshua Sokol ■

Follow-up observations by the European Southern Observatory suggest that LIGO may have seen three gravitational wave signals. The map shows areas of sky swept by the ESO, superimposed on the cosmic microwave background – the embers of the big bang – as mapped by NASA's WMAP



BACKGROUND SOURCE: NASA / WMAP SCIENCE TEAM

Korean rocket

WHO needs subtlety? North Korea's latest rocket launch has heightened fears that the country is developing long-range missiles with the potential to deliver nuclear warheads.

At 0030 GMT on 7 February, North Korea launched what it described as an Earth observations satellite called Kwangmyongsong-4 into orbit on an Unha rocket. The US Joint Space Operations Center confirmed that the satellite had reached orbit, but there were no signs of communication between the spacecraft and the ground as *New Scientist* went to press.

Nations around the world condemned the launch, which came a few weeks after North Korea's fourth nuclear test. The UN Security Council held an emergency meeting to discuss the launch, and promised "significant measures". The launch violates sanctions against the development of nuclear weapons and missiles.

Only boys allowed

SOME mothers may have them. Women in the US whose children risk inheriting severe mitochondrial diseases should be allowed to have the mitochondria in their eggs replaced by those from a healthy donor, says a report by the country's Institute of Medicine. The caveat? They should only be allowed to have sons.

Mitochondria are inherited from the mother, so a daughter passes them to the next generation. In the case of a son, the donor mitochondria will pass to him but no further.

The recommendation has been criticised in the UK, where the go-ahead for mitochondrial replacement therapy was given last year without any such restriction. The Food and Drug Administration requested the report, so its recommendations are likely to become official policy.

Zika in saliva

KEEP on kissing. At least that's the advice for now, with the discovery of active Zika virus in saliva and urine. The finding, by researchers at the Flavivirus Molecular Biology Laboratory in Fiocruz, Brazil, adds to concern following recent confirmation that the virus can spread through sex.

"We are not yet sure if Zika can be transmitted to others through saliva or urine," Myrna Bonaldo, whose team found the virus in the urine of one patient with Zika-like symptoms and in the saliva of another, said last week.

But Jonathan Ball of the University of Nottingham, UK, says the family of viruses that Zika belongs to are primarily insect-borne, spreading from bloodstream to bloodstream.

He suggests there may be a small chance that virus particles in saliva could infect someone with bleeding gums. "The risk from kissing is very low, but not impossible."

"The risk of Zika infection from infected saliva while kissing is very low, but not impossible"

Iberian lynx makes a comeback

WELCOME back. Around 20 Iberian lynx have been released in Spain and Portugal since the start of the year in the latest phase of a reintroduction programme, helping one of the world's most endangered cat species reclaim lost habitats.

In 2002, there were fewer than 100 Iberian lynx in the wild, confined to just two regions in southern Spain. Since then, their population has grown to over 300, thanks in part to an ambitious programme called LIFE Iberlince.

There are plans to release 48 lynx in total this year across seven regions, most from captive breeding centres. These will join the 124 already released since 2014 in Castilla-La Mancha, Extremadura and Andalusia in Spain, and the Guadiana Valley in Portugal.

Last year, the International Union for Conservation of Nature downgraded its status from critically endangered to endangered.

"I'm more optimistic than I was a few years ago," says Miguel Simón, director of the project. But the lynx still faces threats, including a haemorrhagic virus affecting rabbits, its main prey.

A campaign to reintroduce its cousin, the more common Eurasian lynx, in the UK is also gathering momentum, and could get approval from national wildlife authorities later this year. "We're very confident of a positive decision," says Paul O'Donoghue of the Lynx UK Trust.

WILD WONDERS OF EUROPE/OXFORD/NATUREPL.COM

Back for good?

60 SECONDS

Small country, big plans

Outer-space mining is getting serious. Luxembourg has announced an initiative to encourage European asteroid-mining activities. It plans to develop a legal framework to define ownership rights over asteroid minerals and may invest directly in asteroid-mining firms.

Lungs with memory

People who inhaled toxic fumes decades ago are still more likely to die than those who did not (*Thorax*, doi.org/bcfc). A study of 368,000 people in England and Wales showed that someone who lived in a more polluted area in 1971 had a 14 per cent higher risk of dying in 2002-9 than someone who had lived in a less polluted area.

Facebook loss

India's telecoms regulator has ruled that internet service providers cannot charge varying prices for access to different content – and Facebook will be the biggest loser. The ruling means the company is now unable to offer its Free Basics service, which provides free access to selected websites, in India.

Equine emotion

Do horses know when humans are angry? Images of angry and happy people were shown to 28 horses. Angry faces triggered quicker increases in their heart rate and were viewed more with the left eye, behaviour associated with perceiving negative stimuli (*Biology Letters*, DOI: 10.1098/rsbl.2015.0907).

CubeSats take off

Mini missions are go. NASA has revealed some of the 13 CubeSats selected to ride on the Orion spacecraft in 2018. These tiny satellites are a cheap way for NASA to gather more information for future crewed space missions. One will have a solar sail and be sent to a nearby asteroid. Another will gauge the health risks of cosmic rays; others will map the moon.

Grab a bag of stem cells

The launch of the first scientifically approved, mass-produced stem cells is the start of a new age of medicine, says **Andy Coghlan**

AFTER decades of hope, hype and disappointment, say hello to the world's first fully approved, mass-produced stem cell product. Bags of Temcell are packed with 72 million living human cells, and will be launched in Japan later this month as a treatment for people whose organ transplants have turned against them.

Until now, stem cell therapy has mainly been used in unregulated private clinics or as an experimental treatment in clinical trials (see "The dangerous allure of stem cells", below). A handful of treatments have been approved, but these involve injecting someone with stem cells generated from their own cells – a process that can take weeks and doesn't always work. The stem cells in Temcell, by contrast, come from healthy donors and can be multiplied to produce billions of standardised cells.

Developed by a company called Mesoblast in Melbourne, Australia, Temcell will be sold in Japan by JCR Pharmaceuticals. Formerly known as Prochymal, Temcell won approval in Canada and New Zealand, but was never commercially launched in either country. Mesoblast is now carrying out the extra trials that are needed if Temcell is to be approved by US regulators next year.

A new wave

The launch is a milestone, because it propels stem cell therapy into the mainstream pharmaceutical industry. Stem cells from a donor can be cheaply manufactured in large batches, and supplied off the shelf using a business model much more like that for typical drugs, says Natalie Mount of the UK Cell and Gene Therapy Catapult, which helps guide stem cell trials.

Stem cells, the cellular putty from which all tissues in our bodies are produced, have long been touted as medicine's panacea because of their ability to repair damaged tissue or create new organs. "They are giving us the opportunity to do things never possible before," says Martin Evans of Cardiff University, UK, who won a Nobel prize in 2007 for work on embryonic stem cells.

In a few decades, stem cell therapy could be as normal as prescribing conventional drugs. Whether it is eyes, hearts, lungs or spinal cords that need repairing, living cells could be available to do the job, coming pre-packed in syringes or bags, or taken from centralised stem cell banks.

Temcell is just the first of a wave of products that bring this dream closer to reality. Mesoblast has similar products in advanced clinical trials for treating more common conditions, including chronic heart failure, lower-back pain and rheumatoid arthritis. And other companies are hot on its heels. "I believe this is the first of many successes that will be seen over the next several years," says Stephen Huhn, chief medical officer of StemCells in Newark, California.

STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY

Mesoblast's products are made from mesenchymal stem cells extracted from a healthy person's bone marrow. As these cells mature, they form a range of tissues including bone, cartilage, fat and muscle. By extracting the cells at different stages of their development, or by exposing them to a cocktail of growth factors, you can turn them into specific cell types, such as those that specialise in the repair of damaged tissue. The other bonus is that they lack surface features marking them out as foreign, and so can be given to any patient without rejection.

Mesoblast says the stem cells in Temcell were selected for their ability to pacify white blood cells in transplanted tissue that would otherwise attack the cells of the recipient, a potentially fatal condition known as graft versus host disease. "It works by modulating the immune response, blocking pathways involved in

THE DANGEROUS ALLURE OF STEM CELLS

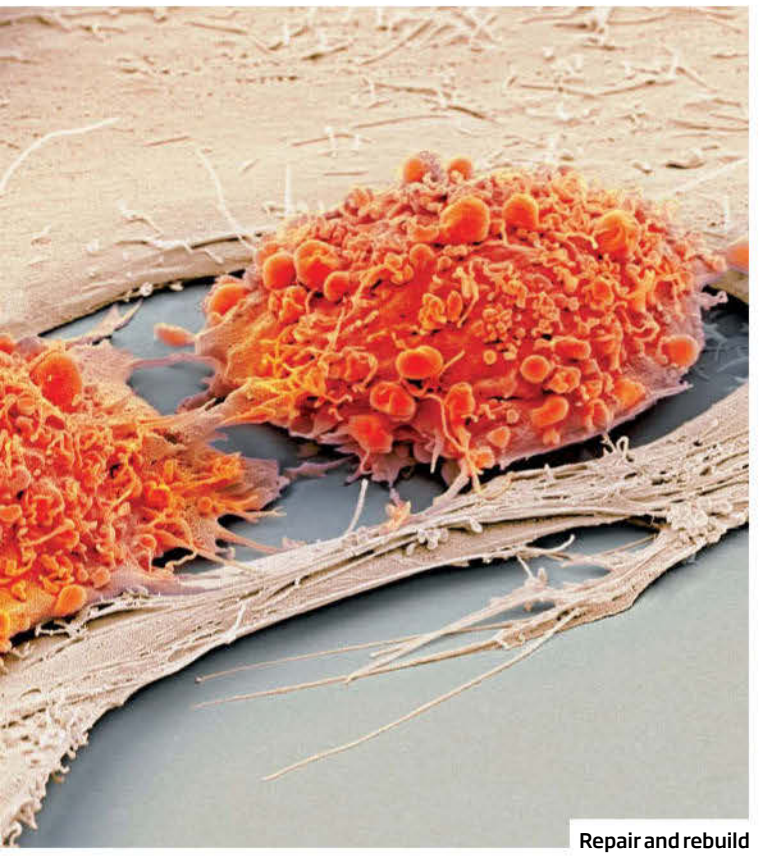
Mass-produced, regulated stem cells are finally coming to market (see main story), but clinics have been using the cachet of stem cells for years to attract people to treatments that have no proof of benefit.

"They make extremely powerful claims, so patients need to think about what the 'red flag' warning signs might be," says Leigh Turner of the University of Minnesota in Minneapolis, who studies the growth of unregulated clinics. "One is if a company claims a single stem cell therapy treats 20 or 30 diseases."

Some unregulated treatments have proven fatal, or caused severe injury. In 2013, Zannos Grekos, a cardiologist offering stem cell treatments through a company called Regenocyte, lost his licence after two of his patients died following reinjection of bone marrow tissue. In Portugal in 2014, a woman treated for a spinal injury with an implant of nasal cells had to have a subsequent painful growth of nasal tissue removed surgically.

Turner estimates that there are between 100 and 200 unregulated clinics in the US. The Food and Drug Administration has issued warning letters to some clinics and the FBI has made arrests in at least one case.

Things could soon get tougher. Sarah Peddicord, a spokeswoman for the FDA, says it is revising its guidance to companies developing products based on human cells and tissues, and will be holding a public consultation on the proposed changes in April. If the changes go through, it will mean the FDA will classify the stem cells used in most clinics as drugs, and they will need to go through a rigorous approval process before they can be used in people.



Repair and rebuild

tissue destruction and the proliferation of highly aggressive [immune cells] from the transplant," says Donna Skerrett, chief medical officer at Mesoblast. "This allows the patient to heal."

In essence, the cells act not as one therapy, as a drug would, but as many acting together in response to biological distress signals from diseased tissue, says Silviu Itescu, Mesoblast's chief executive officer. For example, the cells Mesoblast

"The cells act not like one drug, but like many, responding to signals from diseased tissue"

has developed to treat chronic heart failure were chosen because as well as repairing and rebuilding damaged tissue, they reduce inflammation that causes scarring of heart muscle. The same principle applies in the cells for treating back pain caused by worn down cartilage in the discs between vertebrae.

Evans expects stem cell products to come into their own within two generations. This could see large pharmaceutical firms taking over from biotech companies as the main developers, says Michael West of BioTime, a stem cell company in Alameda, California.

Mesoblast's competitors agree that the launch of Temcell at last paves the way for therapies that have promised much but delivered little so far. "It's an important first step," says Robert Lanza, chief medical officer of Ocata Therapeutics in Marlborough, Massachusetts, which is developing cell-based therapies to treat a cause of blindness. "The launch of a mass-produced stem cell product is a huge achievement, but this particular one is just the tip of the iceberg." ■

Invisibility cloaks fail when travelling at speed

ENGAGE the cloaking device! Fire up the warp drive! Wait, how come the enemy can see us? It turns out that invisibility cloaks stop working when travelling near light speed, and even lower velocities can give you away.

Researchers have been working on invisibility cloaks for a while now. The devices draw on a theory called transformation optics, which enables the design of materials that can bend light around them, hiding anything inside from view. While full-blown cloaks don't exist yet, there has been some progress in making cloaks that hide small objects at certain frequencies of light.

Although a cloak looks like a patch of empty space, Jad Halimeh at the Ludwig Maximilian University of Munich in Germany wondered if there was a way to distinguish between the cloak and nothingness.

It seems so: Albert Einstein's theory of relativity spoils the fun. That's because relativistic effects kick in as an object nears the speed of light, preventing the cloak from working. "If I'm moving with respect to you, what I see as space and time is different from what you see," Halimeh says.

His team studied a simulated cloak capable of hiding a single frequency of green light, and modelled it moving at various speeds in a lab illuminated by that frequency. They found that moving at just 1 per cent of the speed of light (around 10 million kilometres per hour) was enough to start ruining the cloaking effect.

That's because the frequency of light reflecting off the cloak decreases if the cloak is moving away from you or increases if it's moving towards you, similar to the way an ambulance siren's pitch changes as it drives past. That means the light is no longer green – the cloak's operational frequency – which reveals its presence. The effect is even more extreme at higher speeds (*Physical Review A*, doi.org/bcdr).

"It's as if you see some ghost emerging in front of you, popping out of nowhere into existence"

"You start seeing something fishy," says Halimeh. "It's as if you see some ghost emerging in front of you, popping out of nowhere into existence."

We won't need to worry about near-light speed travel any time soon, but Halimeh points out that GPS satellites already have to account for minute relativistic effects, so it's possible that future applications of transformation optics will have to pay attention to Einstein's theory. Jacob Aron ■

PARAMOUNT PICTURES

We can see you

FIELD NOTES Sooam Biotech lab, South Korea

MARK ZASTROW

Another day in the clone factory

Cloning lab aims to save wild species

Mark Zastrow

A DOG lies unconscious on the operating table, as Woo Suk Hwang gently lifts the puppy from her womb. While I watch, another researcher, David Kim leans in to tell me about the original, the source of this puppy's DNA.

He calls it the original, because this nearly born puppy is a clone. Hwang snips open the amniotic sac and the little furball slips out into the world. It's black, wet – and motionless. An assistant wraps it in a towel, massages it gently, and it starts to yelp. Success!

The lab has been cloning domestic dogs for years and is now hoping to do the same with their wild relatives. Hwang and his colleagues want to use their skills to help endangered species. They say they can rescue some of the world's most endangered canids from extinction, including the Ethiopian wolf and the Asiatic wild dog (or dhole).

This has raised concerns among conservationists, who fear cloning will be little more than a shiny distraction from wider efforts to preserve habitats and biodiversity.

Hwang unveiled the world's first cloned dog in 2005, but soon after became an international pariah when he was found to have faked research on human stem cells. His supporters in South Korea funded the creation of a private lab, Sooam Biotech, in Seoul. There he focused on cloning canines – a verified accomplishment – charging bereaved dog owners to replace their recently deceased companions to the tune of $100,000 a pup.

His team also routinely clones pigs with genes susceptible to disease to be used for drug tests, and breeds of cattle prized for their meat. In total, the group produces about 500 cloned embryos every day across all species.

Wolf rescue

Hwang's team takes a skin cell from the animal you wish to clone, extracts its nucleus and then inserts it into an egg with its nucleus removed. The technique is called somatic cell nuclear transfer (SCNT), and the team has now refined and extended it to coyotes and grey wolves, using dogs as egg donors and surrogates. Soon the lab hopes to be producing clones of endangered species. "It is the most meaningful way that we can use the SCNT technology to contribute to society," says Sooam's research director Yeon Woo Jeong.

First up is the Ethiopian wolf, of which fewer than 500 remain, living in the country's high-altitude alpine meadows. The degradation of the highlands because of human expansion has shrunk their range to six enclaves on different mountains, all isolated from each other. Such low numbers of individuals creates low genetic diversity that can reduce the ability of a species to reproduce and survive.

The Sooam lab hopes to preserve these gene pools by cryogenically banking the cells of as many

EERIE: FACE TO FACE WITH CLONED PUPPIES

In the kennel room at the Sooam Biotech cloning facility in Seoul, I get to meet some of the cloned puppies. The first are two 9-month-old German shepherds, cloned for the national police. Their original was a working dog deemed particularly capable and well-disposed. They are endlessly friendly, eagerly jumping up to get my attention.

But it's also incredibly eerie: not only are their coats identical, so are their mannerisms. When they hop down, they twist their bodies to the left – every time, sometimes in unison. The only detail I can use to tell them apart is that one of them has a left ear that points upwards.

Further down is another pair of puppies cloned from the same donor; these ones are just 2 months old. They leap at me with the same unbridled enthusiasm, and one of them also has a perky left ear. I do a double take – a quadruple take, really – glancing back down the row of kennels at their older siblings. It's like looking at a living growth chart.

MARK ZASTROW

individual wolves as possible. If an animal dies in the wild, Sooam could thaw its stored cells, create clones using domestic dog surrogates, and reintroduce them.

Since there are no Ethiopian wolves in captivity, they will first need to be captured. In January, Sooam inked an agreement to collaborate with Arsi University in central Ethiopia through which it hopes to receive permission from the government to collect tissue samples. If it is granted, the lab hopes to be providing cloned pups for repopulation within a year.

Because Ethiopian wolves are very closely related to dogs, the team expects the actual cloning to go smoothly. "I don't think there will be too much of a complication," says Kim.

The lab also hopes to start work later this year on the dhole, fewer than 2500 of which remain in the wild, in mountain forests of India and South-East Asia.

The dhole will test Sooam's cloning expertise: it is more

"Cloning Ethiopian wolves should go smoothly, but is it a distraction from wider conservation efforts?"

distantly related to the domestic dog and classified in a separate genus. In principle, dogs can be surrogates to any canid, but in reality the success rate will vary. "It depends, species by species, on how closely related they are to the dog," says Kim. Hwang's team has attempted to clone the African wild dog, which also belongs to a separate genus. This led to successful impregnations, but no successful births.

So can cloning actually help conserve endangered species? Many researchers are far from convinced. Some feel the lab is operating in a vacuum and its work could even hurt existing conservation efforts.

One sceptic is conservation biologist Claudio Sillero, who founded the Ethiopian Wolf Conservation Programme at the University of Oxford. "They are the last man standing in terms of representing the wilderness of those African meadows," he says of Ethiopian wolves.

Three years ago, Sooam proposed a collaboration to help conserve the wolves, he says. But he turned the lab down, saying cloning wouldn't be worth the time.

Waste of resources?

The most pressing problem for Ethiopian wolves is not genetic diversity or any difficulty in reproducing, he says. It's that they are losing habitat and prey, and are susceptible to diseases spread by local domestic dogs. Genetic diversity could be preserved simply by moving animals between packs, he says. And he worries that politicians presented with a seemingly simple solution will choose cloning over wide-reaching and long-term conservation programmes.

Luigi Boitani, a conservation biologist at the University of Rome, thinks cloning is a "waste of resources" that should be reserved for extreme, near-extinction situations. "I do not see any canid species in this desperate situation yet," he says.

Sooam says its main aim is to provide the technical means to make clones – it's up to governments or conservation organisations to decide when to produce clones, at what scale, and how to reintroduce them. And canids may just be the start, the lab is now looking to clone Siberian musk deer, a vulnerable species whose population has been declining in Korea.

Despite his reservations, Sillero leaves open the possibility that cloners and conservationists could work together to create an insurance policy, perhaps if faced with a sudden extinction. In that case, cloning could be useful. "Who knows?" he says. "Maybe 20 years down the line that will become an accepted practice." ■

NASA

Illuminating experiment

'Dark sunshine' could help find dark matter

THE hunt for dark matter could be lit up by the sun. These mysterious particles, which are thought to make up around 85 per cent of the matter in the universe, might be hiding out inside the sun, producing a bizarre form of light. If so, we already have an orbiting experiment that could spot it.

One reason physicists think dark matter exists is because spinning galaxies don't seem to contain enough mass to hold themselves together – something else must be adding a gravitational tug. Dark matter only interacts with normal matter through gravity, so it can lurk undetected in massive objects like the sun.

Previous research suggested we could pick up a signature of this dark matter in neutrinos coming from the sun, but we've yet to see any that would serve as a smoking gun.

That's why Jonathan Feng of the University of California, Irvine, and his colleagues say we should be looking for "dark photons" instead. Dark light sounds like an oxymoron, but physicists think there may be a "dark sector" – a shadow realm of particles that mirrors the standard one.

"They are very similar to our photons, just in the dark sector," says Feng. They would be created when two dark matter particles within the sun annihilate each other, releasing energy that would beam out as a kind of dark sunshine.

Although we couldn't see these dark photons directly, they should decay into standard particles like electrons and positrons. And it just so happens that the Alpha Magnetic Spectrometer (AMS), a particle detector attached to the International Space Station, is well-situated to catch these positrons.

The AMS is oriented to spot positrons originating elsewhere in the galaxy, but Feng says it should be able to catch a proportion of any events from the sun – between one and 10 positrons over the course of three years (arxiv.org/abs/1602.01465).

"If you can really pinpoint that the

"Detecting even a few of these particles would be enough to claim a discovery"

signal is coming directly from the sun, there aren't too many things it can be," says Stephen West of Royal Holloway University in London.

But he warns there might not be any positrons to see. "There is the distinct possibility the dark photons could decay into something equally dark, and then you wouldn't see it."

Still, Feng is sanguine: "Even a few particles detected would be enough to claim discovery." Jacob Aron ■

Food additives are obesity suspects

Michael Le Page

ICE cream lovers, look away now. Studies on a simulated human gut have added further evidence that emulsifiers, found in most processed foods, might be linked to obesity, diabetes and inflammatory bowel disorders.

Emulsifiers are used to improve a food's texture and to prevent mixtures from separating, particularly in ice cream. Last year, Benoit Chassaing of Georgia State University showed that mice that drank water containing one of two emulsifiers underwent changes in gut bacteria and inflammation of the gut – changes that led to obesity and diabetes in these animals.

However, mice that didn't have any gut bacteria because they had been raised in a sterile environment didn't become ill when given the same additives, suggesting that it is the emulsifiers' effect on the microbiome that is to blame. When the ill mice stopped consuming emulsifiers, their gut bacteria gradually returned to normal.

The question is whether the same might be true for humans. The growing use of emulsifiers has coincided with a rise in obesity and diabetes, says Chassaing, while these conditions aren't as common in countries where less processed food is consumed.

Now Chassaing has supported his findings in mice using a simulation of the human gut. Working with a team in Belgium, he looked at two emulsifiers: carboxymethylcellulose (E566 on EU labels) and polysorbate-80 (E433). When added to a series of flasks that mimic the conditions of the human digestive tract, each caused an increase in the levels of a bacterial protein called flagellin, known to cause inflammation at high concentrations. Chassaing presented the results at a recent meeting at the Royal Society in London.

The simulator results are more convincing than the mouse studies, since lab animals and humans have vastly different gut microbiomes, says Glenn Gibson of the University of Reading in the UK, who studies gut disorders. "The definitive test, however, is obviously a human trial."

Chassaing is now enrolling volunteers for the first human trial to look at the effects of emulsifiers on gut and metabolic health. Carrying out this study won't be easy, he says, as the participants' diets will have to be strictly controlled.

In his earlier work, the mice were given up to 1 per cent of an emulsifier in their water, which Chassaing thinks reflects the levels some people may be consuming. But Patrice Cani of the Louvain Drug Research Institute in Belgium thinks people who eat a balanced diet are unlikely to be exposed to the levels given to the mice.

"Obesity and diabetes are less common in countries that eat less processed food"

Nevertheless, Cani says, we should be concerned. Whatever the results of the human trial, regulators need to rethink the way they test the safety of food, he says, as existing tests were developed before we understood the importance of our gut microbiota and how they can be affected by what we consume. ■

MARIE GENEL/PICTURETANK

Additive alert

Australia plans to track Earth data in real time

IF KNOWLEDGE is power, then some Australians may be about to become very mighty indeed. A bold 10-year programme run by the country's national research agency CSIRO aims to record everything that happens in the environment and make it immediately available to everyone in real time.

The agency wants Oznome to become a "historical, current and future digital representation of everything" in the country by 2025, starting with environmental data. "Like the Human Genome Project, Oznome is a big crazy idea that many people will say isn't possible," says David Lemon, a team leader at CSIRO.

Making it happen will involve finding a way to bring together data from government agencies, researchers, private companies and citizen scientists to offer an unprecedented understanding of how systems connect with each other – whether that's water, energy or agriculture, health or economics. In the long run, historical data from Oznome could be used to make predictions.

"This is kind of the dream for any of us that work with data," says Jeni Tennison, technical director of the Open Data Institute in London. "But it's really, really hard to do." It's both a technical and a cultural challenge: how to build a platform that allows easy data sharing, and how to get people to share their data.

There are ways of making it work. Under a similar initiative in Tasmania called Sense-T, sensors have been placed across the island to measure real-time weather, carbon dioxide levels, the health of animals and farmed fish, water reserves and energy use.

"It's fascinating to see what a community does with access to information in a form they can consume," says Lemon. "To me, this is a taster of what's to come with Oznome." Olivia Solon ■

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INSIGHT False confessions

The sleep-starved tend to say: 'I did it'

Clare Wilson

THE body of 14-year-old Crystal Champagne was found under a bridge in Louisiana in 1996, an electrical cord around her neck. Within a couple of days, her cousin Damon Thibodeaux confessed to police that he had raped and then murdered her.

Thibodeaux had nothing to do with the crime, as DNA evidence later confirmed. But he paid a heavy price for his false statement, spending 15 years in solitary confinement on death row before being released.

False confessions are hard to fathom but surprisingly common. According to New York-based campaign group the Innocence Project, they play a role in up to a quarter of wrongful convictions in the US. In many cases, as in Thibodeaux's, the suspect was profoundly sleep-deprived when interviewed by police.

Now we have proof that severe exhaustion can make a false confession more likely. "It's a milestone," says Lawrence Sherman, head of the Institute of Criminology at the University of Cambridge.

It might seem obvious that tired people can make bad decisions – but there is a long history of interrogators exploiting lack of sleep as an interview tool. In the UK, some notorious 1970s miscarriages of justice involving suspected Irish Republican Army bombers hinged on confessions made after profound sleep deprivation (not to mention systematic police brutality). It is now illegal for police in the UK to interview anyone who has not had 8 hours' sleep in the past 24 hours, unless in an emergency.

But many other countries, including the US, have no such rule. Thibodeaux's confession followed an all-night interrogation, after he had already been up the previous night helping to search for Champagne.

"To the average person, it's inconceivable how a false confession can happen," says Saul Kassin of the John Jay College of Criminal Justice in New York. He says the suspect usually sees confession as a short-term ploy, thinking that when all the evidence is in, their innocence will be obvious. "They believe that in the end they won't have to pay for the confession."

Such a gamble is hard for juries to understand, he says, but a study involving 88 university students might help. They did various computer tasks as part of a fake experiment, then came back for more tasks a week later. At this point, they either slept for 8 hours or stayed up all night.

The following morning they were accused of deleting all the data from the first session by pressing the "Escape" key the previous week, something they had been repeatedly warned not to do. "It's not as awful as confessing to murder, but some of these people feel really bad – they think the experiment is ruined," says team member Elizabeth Loftus of the University of California, Irvine.

When asked to sign a statement acknowledging guilt, half of those who were sleep-deprived complied, compared with only 18 per cent of those who slept (*PNAS*, DOI: 10.1073/pnas.1521518113).

Peter Neyroud of the University of Cambridge says it's possible that students may be more suggestible than the average person in jail. "They may be bright, but they aren't necessarily savvy," he says.

But the work still fills a gap, says Kassin: it is the first to show that, besides impairing people in various ways, sleep deprivation can lead to false admissions of guilt. "In court, there's nothing more persuasive than a study that goes right to the point." ■

MICHAEL DEMOCKER, NOLA.COM/THE TIMES-PICAYUNE

Fifteen years for a lack of shut-eye

Mystery ice age invaders took over Europe

EUROPE went through a major population upheaval about 14,500 years ago, at the end of the last ice age, according to DNA from the bones of hunter-gatherers.

We know from recent studies of ancient DNA that hunter-gatherers who arrived in Europe about 40,000 years ago were largely replaced by farmers from the Middle East about 8000 years ago. Then about 4500 years ago came an influx of pastoralists from the Eurasian steppe. So modern Europe was shaped by three major population movements.

The latest study suggests things were more complicated. About 14,500 years ago, when the continent was emerging from the last ice age, the hunter-gatherers who had endured the chilly conditions were superseded by a different population of hunter-gatherers – though where the newcomers came from is not yet clear (*Current Biology*, doi.org/bcdg).

"The main hypothesis would be glacial refugia in south-eastern Europe," says Johannes Krause at the Max Planck Institute for the Science of Human History in Jena, Germany, who led the analysis.

As climatic conditions improved, hunter-gatherers from warmer areas further south took advantage and migrated into central and northern Europe, he says.

His team studied mitochondrial DNA extracted from 55 ancient Europeans, the oldest of whom lived 35,000 years ago and the youngest just 7000 years ago – a much longer timespan than most previous studies.

"The population turnover in Europe around 14,500 years ago was completely unexpected"

"The population turnover after 14,500 years ago was completely unexpected," says Iosif Lazaridis of Harvard Medical School in Boston.

But he says we will also need nuclear sequences of DNA to better understand this so far unknown episode in Europe's prehistory. "Mitochondrial DNA tells only part of the story of a population," says Lazaridis. Colin Barras ■

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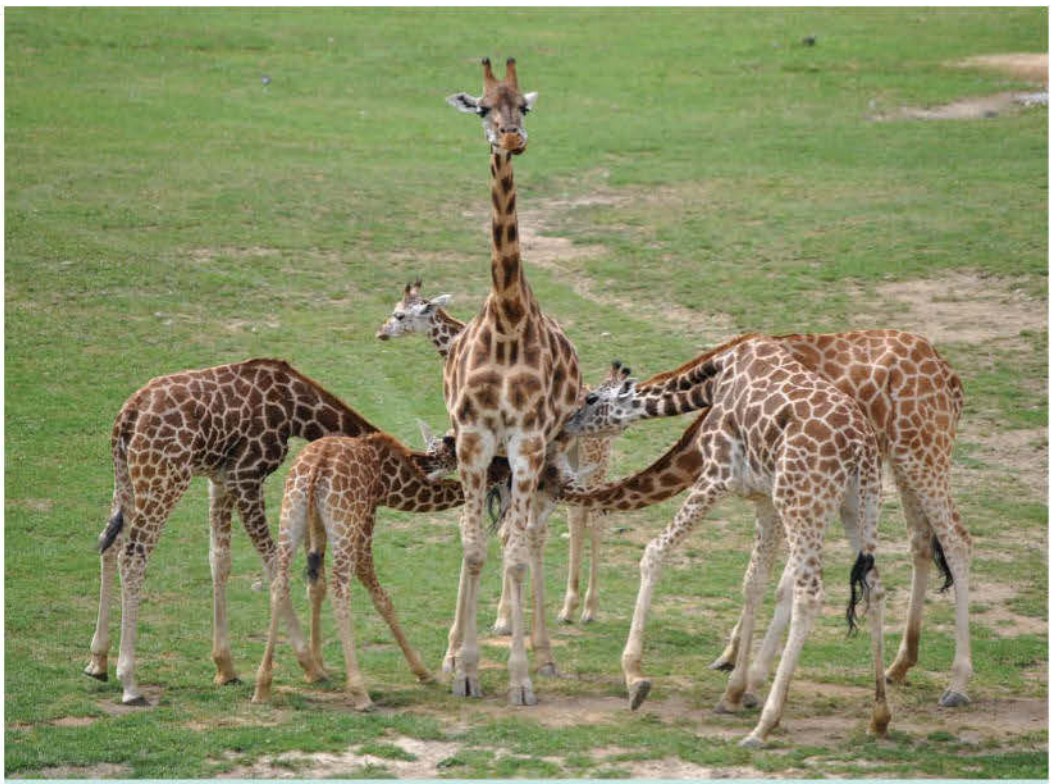


MARKÉTA GLONEKOVÁ

Baby giraffes may be cute but they're also milk thieves

THEY'RE milking it. Baby giraffes use stealth to take milk from giraffes that are not their mothers, at least in zoos.

This sneaky behaviour makes up about 40 per cent of their suckling on average – the highest rate recorded in any non-domesticated mammal. The finding is surprising because milk is costly to produce, so a mother is expected to save it for her own offspring. What is going on?

It might be down to simple theft, according to Markéta Gloneková and Karolína Brandlová at the Czech University of Life Sciences in Prague. The thieving calves usually went in for milk at the same time as the biological offspring, seeming to hide behind them in an effort to conceal their identity. But reciprocity may also be at play: mothers appeared more willing to tolerate calves of mothers that also nursed others.

The pair observed 24 nursing giraffes and 37 calves at four zoos in the Czech Republic. They saw 83 per cent of mothers nursing a calf other than their own, and 87 per cent of calves suckling from a female that wasn't their mother (*Animal Behaviour*, doi.org/bcbw).

Although unexpected, the finding fits with our growing understanding of giraffes. "Recent studies of giraffe sociality show us the existence of an elaborate social system," says Brandlová. "Calves stay together in small groups protected by one adult female while their mothers are searching for food."

Oceans vanish when carbon dioxide rises

HUGE quantities of carbon dioxide could evaporate all of Earth's water off into space. This process might make Earth-like planets around other stars uninhabitable.

Max Popp of Princeton University and his colleagues modelled Earth's climate, and found that adding large quantities of CO_2 to the atmosphere could heat the planet until it leaks water.

They simulated an ocean-covered world slightly warmer than Earth. Adding CO_2 lets the atmosphere retain more heat, which alters wind patterns and creates more clouds that catch even more rays.

Water molecules in the clouds are exposed to ultraviolet rays, which break them into hydrogen and oxygen – and then many of those hydrogen atoms will fly off into space. Oceans would dwindle and eventually disappear (*Nature Communications*, DOI: 10.1038/ncomms10627).

Luckily, it shouldn't happen here. Losing water this way is more of a worry for hotter planets that are closer in to their stars, says James Kasting at Pennsylvania State University. On such planets, any CO_2 released by volcanoes might be enough to pull the trigger. Popp's model might help work out which exoplanets could support life, he says.

Rookie immune cells hit cancer hard

SOMETIMES novices can beat the veterans. Immune cells taken from umbilical cord blood turn out to be better than versions from adults when it comes to killing off leukaemia cells.

The result is a surprise because adult immune cells have lots of experience in recognising and destroying abnormal cells. Fetal immune cells have no such "training", yet excel at the task. "We thought the baby cells would be much tamer," says Paul Veys of Great Ormond Street Hospital for Children in London.

Veys's team injected immune cells from various sources into mice with B-cell lymphoma. When the immune cells came from umbilical cord blood, the tumours soon became packed with CD8 T-cells that destroy cancerous tissue, and vanished. But in mice that received adult immune cells, the tumours kept on growing (*Blood*, doi.org/bccb).

Orangutan couple 'murder' a female

A RUMBLE in the jungle turned deadly. A female orangutan has died after another female and a male attacked her – the first time lethal aggression has been seen between females of the species.

Female orangutans are solitary and rarely fight. In this case, in the swamp forests of Borneo's Mawas Reserve, a young female and her suitor beat and bit an older female. The victim's wounds became infected and she died two weeks later (*Behavioral Ecology and Sociobiology*, doi.org/bcbz).

"We had never seen anything like this before," says Anna Marzec at the University of Zurich, Switzerland. The area is getting more crowded because of habitat destruction, which could have played a role in the unusual act.

Purging old cells extends lifespan

IT'S an extreme take on detox. Clearing out old cells helps mice live longer, and seems to stave off a multitude of age-related diseases.

When cells wear out, they don't always die. Sometimes they hang around, pumping out damaging compounds. Get rid of these cells and a host of benefits ensue, suggest mouse studies by Darren Baker and his colleagues at the Mayo Clinic in Rochester, Minnesota. By tagging the cells with a "suicide gene", the team were able to wipe them out in the animals.

The treated mice lived around 25 per cent longer than untreated mice, on average. "That's the equivalent of extending human life from 80 to 100 years," says Baker. What's more, the mice were less ravaged by age. After six months of twice-weekly treatment, their hearts were healthier and they were better at recovering from stress. Their kidneys had less age-related scarring, and they didn't develop cataracts or cancer until later in life, compared with untreated mice. They even looked younger, because they didn't show the same fat loss as untreated mice (*Nature*, doi.org/bcb2).

The race is now on to find drugs that clear these cells in people. "A few years ago, I would have said we were a long way off," says Baker. "But we've been working with a company and it's easier than we thought."

DARREN BAKER AND JAN VAN DEURSEN

Mini ice age linked to fall of empires in late antiquity

IT WAS a cold century. In AD 536, the first of three giant volcanic eruptions ushered in a mini ice age that coincided with a plague epidemic, the decline of the eastern Roman Empire, and upheavals across Eurasia.

Now we have the first evidence that the disruption to climate continued for more than 100 years, rather than around a decade, as previously thought. The cold lasted until around 660, affecting Europe and Central Asia, and perhaps the rest of the world, too.

Ulf Büntgen at the Swiss Federal Research Institute in Birmensdorf and his team have used tree ring data to show that the eruptions were followed by decades of cooler summers – in some cases 4 °C cooler – probably thanks to the volcanic dust in the atmosphere (*Nature Geosciences*, doi.org/bcdq).

The social turmoil at this time included the plague sweeping across eastern Europe, the Slavs expanding across the continent, the transformation of the eastern Roman Empire, and dynastic change in China. "There was dramatic social, cultural and political change," says Shaun Tougher, a historian at Cardiff University, UK. "Perhaps aspects of the changes were exacerbated by a colder period."

"Suggesting climate caused complex events in history like the fall of empires is controversial," says Francis Ludlow of Trinity College Dublin in Ireland. "Ultimately [though], there can be very little doubt that these sorts of climatic events place great stress on societies, and can sometimes tip them over the edge."

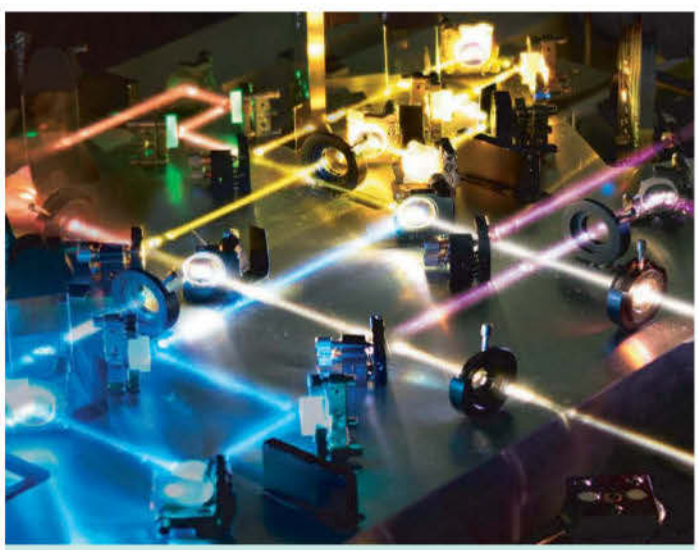
Your brain changes with the seasons

WINTER can get you down. And now it seems that seasons also affect brain functions other than your mood.

Gilles Vandewalle at the University of Liège in Belgium scanned the brains of 28 volunteers while testing their attention and working memory at different times of the year. Although the test scores didn't change with the seasons, activity in some brain areas showed a seasonal pattern: it peaked in the summer on the attention task and in the autumn on the memory task (*PNAS*, DOI: 10.1073/pnas.1518129113).

This suggests that over a year, the brain might work in different ways to compensate for seasonal factors that could affect function, enabling it to maintain stable performance. Vandewalle speculates that the compensation mechanisms might not work as well in some people, for example, those who get seasonal affective disorder in winter.

Many factors, like activity levels or temperature, could be driving the seasonal pattern, but Vandewalle says the results suggest that changing day length is the most likely explanation.



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Catching photons fleeing atoms

IT'S the ultimate high-speed flashbulb. Bursts of light just 380 attoseconds long – 380 x 10^{-18} seconds – have measured how quickly electrons inside atoms respond to light beams.

Theory suggests that electrons take a few hundred attoseconds to kick out a fresh photon after they have been hit by a beam of light, but the precise time was unknown.

To find out, Eleftherios Goulielmakis at the Max Planck Institute of Quantum Optics in Garching, Germany, and his colleagues carefully combined several light pulses of known wavelengths so that some parts cancelled each other out, leaving a super-short pulse behind.

These 380-attosecond-long light pulses can both energise the electrons and act as a camera flash, illuminating the process just long enough to measure the time it takes the electrons to respond.

The team aimed the pulses at gaseous krypton atoms in a vacuum, and found that the electrons in the krypton kicked out UV photons just 115 attoseconds later (*Nature*, doi.org/bcb5).

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Make your own life form

A tabletop lab for hacking DNA to make glow-in-the-dark paint, or even yogurt or beer, hits the market. **Signe Brewster** reports

EVER wanted to create an organism? It's now easier than ever. Take a dash of *E. coli*, a pinch of jellyfish DNA, pop them into your home bioreactor and wait. When done, the bioluminescent paint made by your customised bacteria will glow like a firefly.

At an event for synthetic biology start-up firms in San Francisco on 4 February, Amino Labs showed off the Amino One, a tabletop lab for the consumer market. The two demonstration devices in the room had been gently bubbling away for more than 24 hours, their bacterial brews slowly changing from yellow to red as the hacked bacteria produced paint.

The Amino One shrinks several high-tech lab components into a wooden box the size of a briefcase. As well as make paint, beginners will be able to modify bacterial cells to create medicinal chemicals, scents and even foodstuffs such as yogurt, beer and bread.

The Amino One comes with a couple of basic recipes that walk users through the steps needed to create customised bacteria. To make the red bioluminescent paint, for example, you simply insert the kit's K-12 strain of *E. coli* and jellyfish DNA into the bioreactor. The Amino One then raises the temperature inside the chamber, prompting the bacterial cells to open their membranes and allow the DNA in.

Another chamber supplies food and the bacteria multiply in a tube that runs along the top of the device. You can keep an eye on pH and temperature via the device's screen or an app. When finished, the Amino One cleans itself and resets for your next creation.

Another starter recipe teaches users how to tweak *E. coli*'s metabolic pathways to produce violacein, an anti-parasitic compound used in cancer research. Amino Labs plans to release other starter recipes soon.

"If the kit can inspire a kid to be creative with DNA, that's more important than learning to use a pipette"

CEO Julie Legault says she initially had the idea for a pocket-sized Tamagotchi-like device that would allow people to keep and care for bacteria. But the Amino One promises to be more useful.

Schools already use similar tabletop kits to teach children the basics of bioengineering. However, Amino Labs wants people to improvise, hacking together different scents and materials. Why not throw coffee in with your red paint recipe and see what happens?

"The imagination part of this kit is so much more valuable than the actual mechanics of growing and engineering cells," says biologist Christina Agapakis, who is the creative director at organism-design company Ginkgo Bioworks in Boston. "If this kit can inspire a kid to imagine themselves as a scientist and to be creative about what they might one day do with DNA, then that's much more important than learning to use a pipette or what temperature bacteria need to grow."

Amino Labs will ship the first batch of Amino Ones in March to people who backed its Indiegogo crowdfunding campaign. Early adopters will pay $799, but the price is expected to fall to a few hundred dollars once the company begins mass-producing the devices in 2017.

For now, Amino Labs advises against consuming anything that comes out of its machine. Baking and brewing will require a future upgrade that adds a yeast-processing capability and a component that tests whether your concoctions are safe to eat.

Legault hopes the Amino One will present a positive side of synthetic biology, countering the bombardment of messages about genetically modified organisms.

"It's really misunderstood by the public," Legault says. "If you get the hands-on initial experience, you actually feel more comfortable taking part in the conversation about ethics." ■

AMINO LAB

Interior design: biology gets stylish

INSIGHT Artificial Eyes

PAOLO PELLEGRIN / MAGNUM PHOTOS

More than meets the eye

Worth a thousand words

Photo troves offer fresh ways to see the world, finds **Aviva Rutkin**

IN 2015, humanity put 2 or 3 trillion photographs on the internet. Our faces, our streets, our friends – all online. Now, researchers are tapping into this vein of information, studying photos in bulk to give us fresh insights into our lives and our cities.

In Singapore, a project called AirTick is aiming to use these photos to get a handle on air pollution. This is a serious problem in south and east Asia where schools and factories shut down when pollutants reach dangerous levels. The World Health Organization estimates that one in eight deaths worldwide are caused by air pollution.

Built by a team at Nanyang Technological University, the AirTick app estimates air quality by analysing photos of city streets en masse.

The app examines photos from large social sharing sites, checking when and where each was taken and how the camera was oriented. It then matches photos with official air quality data. A machine learning algorithm uses the data to work out how to estimate the level of pollutants in the air based solely on how it appears in photographs.

The end goal is for ordinary people to get accurate real-time estimates of the air quality in their neighbourhood. Rather than using air pollution sensors, which are expensive and not widely owned, people can use the cameras on their smartphones, which they carry with them. The project will be presented this month at the AAAI Conference on Artificial Intelligence in Phoenix, Arizona.

Other kinds of photo hoards are also finding alternative uses. At Columbia University in New York City, urban scientists are using Google Street View to help them study the city, without leaving their office chairs.

"Scouring streets virtually makes it possible to do in a single month what would typically take three years"

The team is scouring the pictures to find infrastructure snags that heighten the risks of accidents involving pedestrians and cars – work that traditionally meant trawling the streets with clipboards, noting dodgy intersections and badly designed crossings. Project leader Andrew Rundle says the virtual method is far faster and cheaper, capable of completing in a single month the amount of work that would typically take three years.

In their latest project, Rundle and his colleagues combed through 532 intersections in New York City, noting features like traffic lights and crossings. Combining the observations with a database of car-pedestrian collisions, they found that accidents were more likely at corners with billboards, bus stops and pedestrian signals, suggesting those parts of the city could use improvement.

This isn't the only project involving Google Street View: Yahoo Labs in Barcelona used it to build a program that finds the most visually appealing route from A to B. Other projects need more specific photos. Computer scientists at Carnegie Mellon University in Pittsburgh built a program to assess road damage from crowdsourced dashcam images. In London, our photo brain is being used to figure out which streets encourage walking; in North Carolina, to get a sense of how different neighbourhoods might affect children's health.

We're seeing more and more of the world through digital eyes. But we're only beginning to understand how to our use our new, digital sense. ■

3D-printed display lets you explore data with touch

IF YOU can't see, how do you explore images? A display called Linespace – developed at the Hasso Plattner Institute in Potsdam, Germany – has an answer. Linespace is made from the head of a 3D printer attached to the kind of drafting table used by designers and architects. It lays down material to create touchable images, maps and designs on demand.

"The objective is to let blind users visualise and make sense of complex spatial data just like sighted people," says Patrick Baudisch, who led the project.

Baudisch's team has written a number of apps for Linespace. One called Homefinder allows people to search for an apartment on a city map. Users can gesture at areas they want to zoom in on and get a feel for where properties are in relation to roads, public transport and shops.

"The possibility of easily creating raised images cheaply and efficiently has so far been elusive – so we are excited about this type of development," says Steve Tyler at the lab of the Royal National Institute of Blind People in Peterborough, UK.

The RNIB has done some work of its own in this area. Tyler says that keeping the technology affordable is the big challenge. Baudisch estimates that a commercial version of Linespace could cost less than $1000." Paul Marks ■

HPI

Feel your way around

Flying with hydrogen

A water-emitting drone hints at cleaner ways to fly, says **Niall Firth**

IT ONLY lasted 10 minutes and the guys in woolly hats and high-vis jackets looked like any other drone enthusiasts. But this short flight was the first by an aircraft powered fully by solid hydrogen.

The experimental drone runs on pellets that emit only water vapour when they burn. The fuel cell is also three times as light as a comparable lithium battery. One day the technology could help make commercial aircraft lighter and cleaner.

"The idea was simple: stick solid state hydrogen fuel into a drone and fly it – but it's tricky to do," says Phil Anderson at the Scottish Association for Marine Science in Argyll, UK, where the flight took place.

Just as hydrogen-fuelled cars have been eclipsed by electric vehicles, the idea never really took off with aircraft either. Previous efforts such as the Cryoplane project from Airbus used large tanks of liquid hydrogen kept at super-low temperatures. But the tanks were too big to be practical. Storing hydrogen as a pressurised gas is also not very efficient.

"The idea is simple – just stick solid hydrogen fuel into a drone and fly it. But it's tricky to do"

The new system, designed by UK firm Cella, uses around 100 solid pellets packed into a cartridge. The 1-centimetre-long pellets are made from a chemical compound that produces a steady stream of hydrogen as it is gently heated. This gas is converted into electricity in a fuel cell that runs the drone's rotor. The inclusion of a polymer stops the compound melting and helps it release hydrogen at a lower temperature.

Anderson thinks a future version of the drone would be perfect for the environmental and climate monitoring that his team carries out in the Arctic and north Atlantic. Because it is lighter than battery-powered drones, it can fly for longer. The test flight could have gone for 2 hours with the fuel it had on board, says Anderson. "Unlike with a battery, if you put in twice as much fuel you can go twice as far."

Plus, it's cleaner. "The main thing is it just produces water vapour," says Anderson. "A lot of the science we want to do is looking at trace gases so we can't have contamination."

Because the drone's propeller is its only moving part, it is also not susceptible to an effect called carburettor icing that can prevent petrol drones from operating in extreme cold, he says. He hopes to have a hydrogen drone carrying out research science in the next couple of years.

Tantalisingly, the technology might not just be for drones. It could be used in city cars and eventually provide hydrogen power for commercial aircraft, says Anderson. Cella is already working with French aviation firm Safran to produce pellet-powered fuel cells that provide auxiliary power for planes – such as for in-flight entertainment and galley lighting.

"If they can do what they claim, then they have a much bigger commercial space than just drones," says Missy Cummings at the Humans and Autonomy lab at Duke University, North Carolina. ■

SAMS

Ready for the long haul

ONE PER CENT

Robot blends in

This 3D-printed robot chameleon, built by a team at Wuhan University in China, can change colour to match its background. The robot is covered in plasmonic displays that exploit the interactions between nanoscale structures and electric fields to produce colours: changing the electric field changes the colour. It uses sensors to detect the background colour before selecting the appropriate electric field (*ACS Nano*, doi.org/bcdk).

"I'm going to be a dad!"

The Fitbit can track more than your steps. A Reddit user who turned to the forum thinking his wife's Fitbit was faulty was quickly given an alternative reason why the device was reporting unusually high heart rate and fat-burning levels.

Game on for AI

Google DeepMind just played its way into the 90s. Having beaten the European champion at the ancient game of Go and mastered several video games from the Atari 2600, a console from the 1980s, the team has created an artificial intelligence that can navigate 3D mazes similar to those found in 1993 shooter game *Doom* (arxiv.org/abs/1602.01783). It does so just by looking at the screen – an ability that could be useful for operating in the real world.

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NewScientist

Slaves to the white stuff

TOILING outdoors when it is super hot and dry won't appeal to most, but for these workers in Gujarat, India, it is their lifeline. From October to April – the dry season – the *agariyas*, as they are called, labour from before dawn until dusk at the salt pan known as the Little Rann of Kutch.

First, they pump up water 10 times as salty as seawater from bore wells into the pan, and wait for it to evaporate. Then they rake the salt left behind into piles, and let it drain further. From each plot of roughly 25 metres by 25 metres, they can harvest 10 to 15 tonnes of salt every 15 days. Their reward is just 60 rupees, or 90 US cents, per tonne. The brine burns their skin, and in the monsoon months many are without work.

The 5000-odd families who make their living in this way receive little government help. The region is a designated sanctuary for wild asses, meaning their work is considered illegal.

Photographers Luke Duggleby and Mikel Landa visited 25 countries to find places where salt is produced according to centuries-old traditions. The results are collected in their book *Salz Der Erde* ("Salt of the Earth"), published by Mare Verlag. Sam Wong

Photographers
Luke Duggleby and Mikel Landa
lukeduggleby.com

So long, suckers?

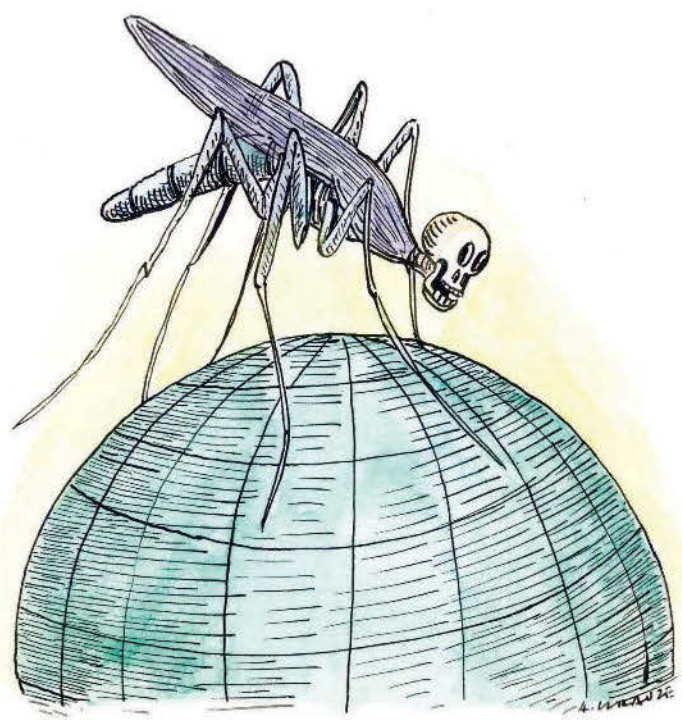
The spread of Zika virus has reignited talk of wiping out pests like mosquitoes. Should we hit the kill switch, wonders **Fred Pearce**

A RACE is on to do something about Zika virus. Any vaccine is years away, so that means doing something about its vector, the *Aedes aegypti* mosquito.

Genetic engineering techniques make it possible to conceive of obliterating this insect entirely. But would there be an ecological downside to exterminating a creature whose only purpose seems to be to bother us?

As with many predictions involving complex natural systems, a definitive answer is impossible. Some ecologists worry about small changes having big unforeseen effects, and liken the complexity of ecosystems to that of an aircraft. Removing the odd rivet seems harmless – until it suddenly falls out of the sky.

But in reality, ecosystems seem to be mostly more resilient than planes. And nobody has come up with a key ecological job done by mosquitoes that other insects couldn't do just as well.



In addition, the world is full of examples of local mosquito eradications that have not precipitated ecological meltdown. Where there has been damage to other species, it tends to be a by-product of the method used – draining marshes or spraying insecticides – rather than the loss of the insects themselves.

The leading plan for tackling Zika in Brazil is to flood populations of *Aedes* with males engineered to pass on a gene that is lethal to offspring. This has been done in the north-east of the country since 2011 to try to control dengue fever, another disease *Aedes* carries.

Similar methods have been used before to tackle various other insects, notably the Sterile Insect Technique, which swamps populations with sterile males.

Political animals

Donald Trump's posturing often seems like a classic alpha display, says **Christopher Boehm**

DONALD TRUMP'S attempt to be the Republican party nominee for the US presidential election has often defied pundits, who initially dismissed his chance of gaining any real public support.

Cue various attempts to explain how this colourful character came to the fore. For my money, I turn to primate politics and the tactics of alpha males. His model of political posturing echoes what I saw while studying Tanzania's wild Gombe chimpanzees.

One stood out: Goblin, an alpha male. He threatened or attacked rivals who looked like they might challenge him, often acting sharply and pre-emptively. Similarly, Trump knows who and when to attack to maximise intimidation.

In an attack, the male chimp's long black hair stands on end as he charges at his rival, which may either race up a tree screaming or stand and fight. Trump's competitors have mostly been racing up trees, though nearest rival Ted Cruz has started to fight back – last week he beat Trump into second place in Iowa.

Before Goblin's time, there was Mike. He was an innovator, noisily using oil cans in his displays and terrifying peers. Trump has innovated in a similar way. His oil cans are his bald insults, his threats against the Republican establishment and the media, and his freedom from relying on contributions from those with vested interests. The billionaire says his campaign is self-funding and that he cannot be bought.

"Trump's competitors have mostly been racing up trees, though rival Ted Cruz has started to fight back"

The latter is important because the number one disease of US democracy is a lobbying system that amounts to institutionalised bribery. Our political world has become one of carefully controlled, poll-driven candidacies funded by lobbies.

The result has been a swarm of

It has been used in the Americas to fight the Mediterranean fruit fly and the screw worm.

Back in 2002, the International Atomic Energy Agency took me to Africa to see how releasing male tsetse flies irradiated to make them sterile had eradicated the insect from the island of Zanzibar, and with them trypanosomes, the parasite they spread that brings sleeping sickness to humans and cattle. It worked but it was hard; it took $5 million and 8 million sterile males to eradicate Zanzibar's 10,000 flies. Fears of a wider effect on biodiversity proved unfounded.

Well before this, in the late 1950s, the world may have come close to eradicating malaria by targeting its host, the *Anopheles* mosquito, by spraying the insecticide DDT wherever it lived. This was before concerns about wider toxicity to wildlife saw DDT use curbed. The mosquitoes and the disease returned.

Nobody should underestimate the difficulty of fighting one of the world's most successful insects. But it is worth remembering that once, despite concerns about nature's fragility, we nearly wiped them out. ■

Fred Pearce is a *New Scientist* consultant

opportunistic insiders working within a system that has wholly captured them. Finally, though, the public worm is turning. In a year when independence really matters, Trump is refreshingly independent, as is Democrat contender Bernie Sanders.

If Trump defies his critics and emerges from the electoral jungle victorious, it will be interesting to see if he is as aggressive in getting things done for those who elected him as he has been in trying to be alpha male of an entire planet. ■

Christopher Boehm is a professor of biological sciences and anthropology at the University of Southern California

ONE MINUTE INTERVIEW

Sperm with added aggro

There's more than mere sperm in ejaculate, and these smuggled extras may change female behaviour, says **Eleanor Bath**

PROFILE

Eleanor Bath is an evolutionary biologist in the department of zoology at the University of Oxford. She presented her research at the Falling Walls Lab in Berlin, Germany

What got you interested in how mating affects female behaviour?

For decades, my mum told me stories about how when she was pregnant with me she used to feel bursts of irrational rage towards everyone around her. Yet she didn't blame the woman who stole her taxi while she was going into labour, nor the colleague who'd forgotten about the time difference and called her up at 4 am. She blamed me, her unborn child. After 26 years of hearing these stories and taking the blame, I am researching female aggression after mating.

So was your mum on to something?

She is actually backed up by a fair bit of science. Female aggression rises after mating in a lot of species: you find it in mammals, birds, fish… I even found that in fruit flies, mated females will spend twice as long fighting over food as virgin females.

That's understandable enough, surely?

On the surface, yes. The theory is that once you're producing eggs, you get this signal from your body saying "I need more nutrients", and so you go out and get more food. Just because you need more doesn't mean more food is available, so you may need to get aggressive to get a bigger share of limited resources. But what I wanted to find out was whether the flies actually needed to be making eggs for this aggression to appear.

How did you go about finding out?

I mated sterile female fruit flies, which cannot produce any eggs, with normal males. And I found exactly the same increased aggression: mated females will fight for twice as long as virgin females, regardless of whether they are producing eggs. That's counter-intuitive.

So what is causing the aggressive behaviour?

There seems to be a male influence on female aggression, possibly transmitted through the ejaculate itself. There is a whole lot of stuff in ejaculate besides sperm. Molecules called seminal fluid proteins (SFPs) may be having a big effect. We know they can do things like increase female egg production, reduce receptivity to re-mating, and alter sleep patterns. SFPs can find their way into the brains of the females. It looks as if they are serious manipulators of female behaviour.

Could there be parallels in humans?

That would be wildly speculative. What I can say is that the ejaculate of humans and other mammals does contain SFPs. There's one called ovulation-inducing factor, which does exactly what it says on the tin. For example, camels and llamas need to mate before an egg is released. Humans, on the other hand, are spontaneous ovulators – once a month an egg is released regardless of everything else that's happening – so we cannot say if this particular SFP has any impact on human female fertilisation or behaviour. But work is being done to see whether SFPs might improve the success rate of IVF, for example.

What does your mum think of your findings?

She's certainly less likely to blame me now! I just feel sorry for my dad.

Interview by Sean O'Neill

We're sitting on a mould mine

Mushrooms can protect us from viruses, save the bees and even help to tackle climate change, says **Paul Stamets**

Tell me about the hat you're wearing.
It's made from a birch polypore mushroom. Our ancestors realised that you could get this tough bracket fungus off birch trees, hollow it out and put fire in it and carry it for days. This enabled the portability of fire that is so critical for human survival.
When the same mushroom is boiled and stretched, it produces a fabric. There are only a handful of people in Transylvania who are making these hats now. Because of deforestation and the difficulty of finding large-enough mushrooms, the hats are becoming very rare.

What started your fascination with mushrooms?
One day I decided to try some psilocybin [magic] mushrooms. After eating a whole bag of them, I climbed to the top of an oak tree just when a huge lightning storm with boiling black clouds was rolling in. I was thinking, "This is it Paul. If you make it through this, what does it mean to you?"

The biggest problem in my life at the time was a bad stutter. It was a social phobia that made dating girls really difficult. So I started repeating a mantra: "Stop stuttering now, stop stuttering now." On my way back, I ran into a girl who I liked a lot but was always too shy to talk to. "Hi Paul, how are you doing?" she asked. I answered, "I'm doing just great!" That was basically the end of my stuttering.

How do you think this stopped your stutter?
Recently scientists have discovered that psilocybin stimulates neurogenesis – it helps build neurons. I believe that's what happened to me; that it helped to remap a neuronic pathway in my brain.

Have mushrooms given you anything else?
Yes, what mushrooms have taught me is the interconnectedness of all life forms and the molecular matrix that we share. I no longer feel that I am in this envelope of a human called Paul Stamets. I am part of this stream of molecules that are flowing through nature, that are becoming eddies of life. I am given a voice, given consciousness for a time, but I feel that I am part of this continuum of stardust into which I am born and to which I will return at the end of this life.

Many people in Western culture are almost afraid of mushrooms generally. Why is that?
Many people are mycophobic [mushroom fearing]. People from Japan, from Eastern Europe, from China, from Mexico, they are much more mycophillic. In the West, we see mushrooms as signs of decomposition and death, whereas in Asia mushrooms symbolise regeneration and rebirth. That is a cultural chasm we are now crossing.

PROFILE
Mycologist **Paul Stamets** founded and directs research at Fungi Perfecti (fungi.com) in Kamilche Point, Washington. He was named Invention Ambassador by the American Association for the Advancement of Science in 2014 for his pioneering studies of uses for mushrooms

Do mushrooms have medical potential?
After 9/11, the US Department of Defense (DoD) was worried about an attack by biological weapons, especially one using weaponiseable bacteria and viruses.
As part of the Project Bioshield programme I submitted more than 500 mushroom extract samples to see what might work as a defence. We got the best results of all the hundreds of thousands of samples submitted, including pharmaceuticals, against a variety of viruses like cowpox, smallpox, herpes and flu.

We were once forest creatures. With the advent of agriculture, roughly 12,000 years ago, humans embarked on deforestation, inadvertently unravelling immunological mycelial networks that have protected us and others for aeons. Viral diseases that have jumped from other animals to humans, such as bird flu and Ebola, are signs, in my opinion,

STUART ISETT

of this loss of forested habitats and the corresponding mycodiversity.

Can mushrooms offer protection to animals?
Bracket fungi immunologically protect, and connect, the animals of forest lands – from bees to birds, bats, bears, pigs and people. For example, I was growing mushrooms on a compost of wood chips, and was surprised to see that the bees had pushed the wood chips aside and were sucking on the branching, vegetative part of the fungi, called the mycelium. It turns out that bees and maybe other organisms use certain anti-fungal compounds found in decomposing wood to detoxify themselves. Without the fungi, the bees can no longer rid themselves of fungicides, herbicides and other poisons, so they get sick.

The company I started, Fungi Perfecti, has now developed "myco-honey" using extracts derived from mycelia. When bees eat it, their viral counts plummet, they live longer and the colony increases its survival capacity.

How do fungi destroy toxins?
The DoD wanted help breaking down a neurotoxin that Saddam Hussein used to kill 20,000 of his own people. A lab they were working with approached me and asked if I could train mycelia to break it down. I gave them cultures of 28 species and instructed them to increasingly expose these to the toxin over time. Within six months, two of the strains I had given them had adapted to that neurotoxin as their sole nutrient source, and produced enzymes customised to break it down, eating the toxin and rendering it harmless.

Mycelia constantly learn from their environment. They can help remediate oil spills, and break down pesticides and herbicides. I am convinced that there is not yet a single carbon-based toxin that we could not train mycelial networks to break down.

What else could mushrooms be used for?
Some 400 million years ago there was a 10-metre-high fungus called *Prototaxites* that dotted the landscape – the tallest organism on Earth in that era before vascular plants. Future space pioneers should carry mycological communities with them for terraforming other planets: to break down the rocks, help bring minerals into plants, and set up the biodynamics of an ecosystem.

Could mushrooms restore our own planet?
Mushrooms and their mycelia can rehabilitate habitats that have suffered traumatic impacts from pollution or deforestation. I call mushrooms soil magicians. These are the grand recyclers of nature, instrumental in the decomposition that creates the soil that gives rise to biodiversity.

> **"Future space pioneers should carry fungi for terraforming other worlds"**

One avenue for tackling global warming is to use mycelia to build up the carbon sequestered in soils. For example, about 30 per cent of the biological carbon in the soil of mature forests is fungal in origin. This "mycomass" can hold far more carbon than most trees.

You call the vast underground networks of mycelia Earth's "natural internet" and claim they are intelligent. Do you stand by that?
Let me answer that this way: my brother Bill used to be my biggest critic. He said, "Paul, you can't say that nature is intelligent." I said, "Bill, you are saying that nature can't be intelligent when it gave you the very brain that gave you the ability to conceive this concept?"

Do you feel that science has underestimated the importance of fungi?
Absolutely. Prejudice against them has permeated the sciences: it is a form of biological racism. On the plus side, this general avoidance of mushrooms has left the field wide open for me – and a few others – to explore. ■

Interview by Richard Schiffman

The longest decay

A hunt for one of nature's most elusive processes could reveal why matter dominates our universe, finds **Matthew Chalmers**

FRANCESCO BONGIORNI

IF YOU'D been watching since the birth of the universe, you wouldn't have had a hope of glimpsing one. Hang around for a trillion trillion years, long after the stars have fizzled out and cosmic heat death beckons, and you still wouldn't be close. In fact, believe the laws of physics and you could spend an eternity searching in vain.

Physicists don't let such odds deter them. Across the planet, thousands are mounting a search for one of the rarest processes in nature: a form of radioactive decay that, if sighted, could reveal why the universe contains anything at all.

Radioactive decay is nature's alchemy. It is capable of transforming certain heavier elements into lighter ones, but it runs on its own schedule – some elements have lifetimes of minutes, others millennia. These radioactive processes are vital to our very existence, with one collection known as beta decays helping to power the sun. The most familiar type of beta decay causes a neutron in an atomic nucleus to transform into a proton, ejecting an electron and an antineutrino, the neutrino's antimatter partner, in the process.

In 1935, physicists predicted that certain nuclei might undergo two such beta decays at once. This rarest known form of nuclear decay is only likely to occur in a given nucleus once every 10^{19} to 10^{24} years. Keep watching a large enough collection of atoms, however, and you improve your chances of seeing one happen, with the result that we have now spotted it in 11 different heavy nuclei.

Even the rarity of these decays has nothing on what researchers are looking for now. Neutrinoless double beta decay involves two neutrons transforming into two protons and two electrons – without producing any antineutrinos at all (see diagram, page 32).

For this vanishing trick to occur, something remarkable needs to happen. The two antineutrinos need to effectively cancel each other out, much as particles and their antiparticles mutually "annihilate" when they come into contact. If these two identical particles are to neutralise each other, however, neutrinos and their antiparticles must be one and the same – they must be both matter and antimatter at the same time. When it comes to fundamental particles of matter, says Steve Biller of the University of Oxford, "there is no other particle that this is true for".

It wouldn't be the first time neutrinos have upset established theories. Even though they were spotted in the wild for the first time in 1956, there's still a lot we don't know about them. Part of the problem is how little notice they take of everything else in the universe – billions pass through you every second from the sun, and they would emerge unscathed on the other side of a light year of lead. Even the seemingly simple question of whether or not neutrinos had mass (they do) was only resolved in the early 2000s, a result deemed so significant that it won last year's physics Nobel prize. But we still don't know why their masses are so small – or why they come in three "flavours".

Matter vs antimatter

In 1937, the Italian physicist Ettore Majorana predicted that mass-bearing neutrinos would possess an intriguing property. As the only fundamental particle of matter with no electric charge, it would theoretically be possible for them to be their own antiparticles – a new breed of "Majorana neutrinos" for which the distinction between matter and antimatter was obsolete. In this guise, neutrinos could interfere with processes primed to create equal amounts of matter and antimatter, throwing the symmetry out of kilter. That in turn might explain how a small quantity of matter managed to escape annihilation in the first moments of the universe – and went on to make stars, planets and us.

"Our very existence might be connected to neutrino mass and neutrinoless double beta decay," says Werner Rodejohann of the Max Planck Institute for Nuclear Physics in ›

Heidelberg, Germany. Discovering such a decay would be a major achievement, he says, and in some sense it would be even more fundamental than the long-awaited sighting of the Higgs boson. That discovery confirmed a long-standing theoretical model. This one would show that current theories of physics are incomplete, and hint at where to take them next.

The problem is, in more than 50 years of searching, only a single putative instance of neutrinoless double beta decay has been observed. First reported in 2001 at the Gran Sasso laboratory in Italy, it has become known colloquially as the Klapdor-Kleingrothaus decay after Hans Klapdor-Kleingrothaus, the University of Heidelberg researcher who stood by its veracity for over a decade. Most physicists remained unconvinced, but the result tantalised anyone with an interest in the decay. "We would have loved to play around with the new physics, but if you were a betting person you would have had to have said it was unlikely," says Biller.

> "From lots of perspectives neutrinos look like oddballs, so we may well find something strange"

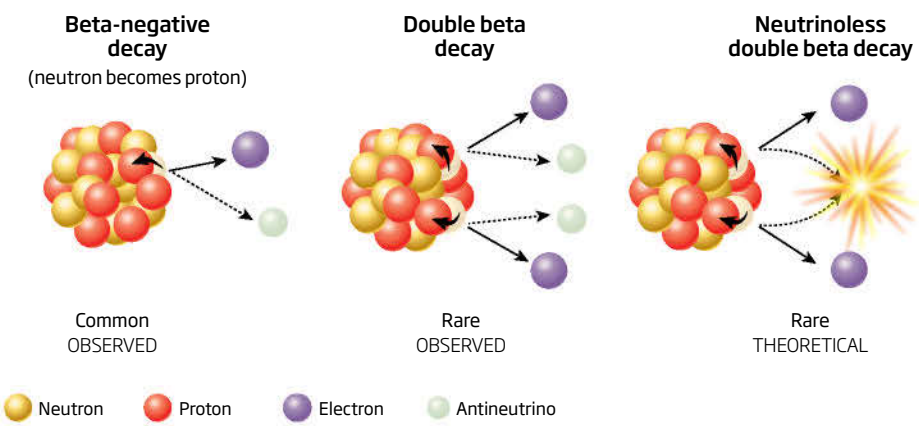
The drive to confirm or rule out the Klapdor-Kleingrothaus event led to a burst of activity in the field, inspiring the construction of three experiments, at Gran Sasso, New Mexico and Japan. In the past couple of years these seem to have conclusively ruled out that event. At long last, says Steve Elliott of the Los Alamos National Laboratory in New Mexico, researchers in the field can stop using the claim to define their next steps.

Those larger experiments have also refined our measurement of the decay lifetime, pushing the minimum time you would expect to wait to see an individual nucleus disintegrate via neutrinoless double beta decay out to 10^{25} years.

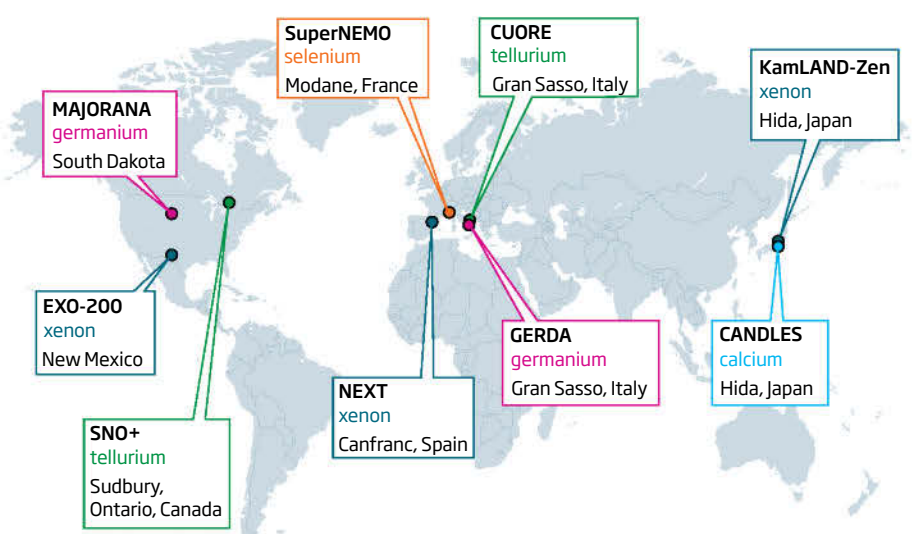
But hope is not lost. There are now at least eight new or revamped experiments looking to spot the process, and these detectors just might be big enough and sensitive enough to smoke it out. They all operate along roughly the same lines: amass as much as possible of an extremely pure isotope deep underground, where it is shielded from the bombardment of cosmic particles that could swamp a detection. Then, be patient. Rely on the law of large numbers for a decay to eventually occur.

Rarest of them all

All radioactive beta decays are expected to produce some kind of neutrino. If the neutrino is its own antiparticle, however, one in a hundred trillion trillion decays will result in no neutrinos at all



Detecting such rare decays requires isolating trillions of atoms deep underground, and waiting for one to happen. Many such experiments are under way across the world, using a variety of isotopes



Staying neutral

Even so, it's a tough ask. The teams are looking for events so rare that the background from natural radioactivity cannot exceed one event per year per tonne of material. Even a banana, owing to its trace concentration of potassium, emits around 15 radioactive decays a second, more than enough to overwhelm any bona fide signal.

At present, only a handful of isotopes are both sensitive and abundant enough to be useful for experiments of this scale. Each has its merits, but all eyes are currently on germanium. Its concentrated crystalline form results in a more compact apparatus that can measure the energy of the two emitted electrons very precisely, making it easier for researchers to distinguish true decays from background events. GERDA, the Gran Sasso

experiment that helped bust the Klapdor-Kleingrothaus decay, is now gearing up to use 40 kilograms of germanium. Its main rival, the Majorana Demonstrator, located in a former gold mine deep beneath the town of Lead in South Dakota, is hot on its heels. It will be taking data with a 44 kilogram device by the summer.

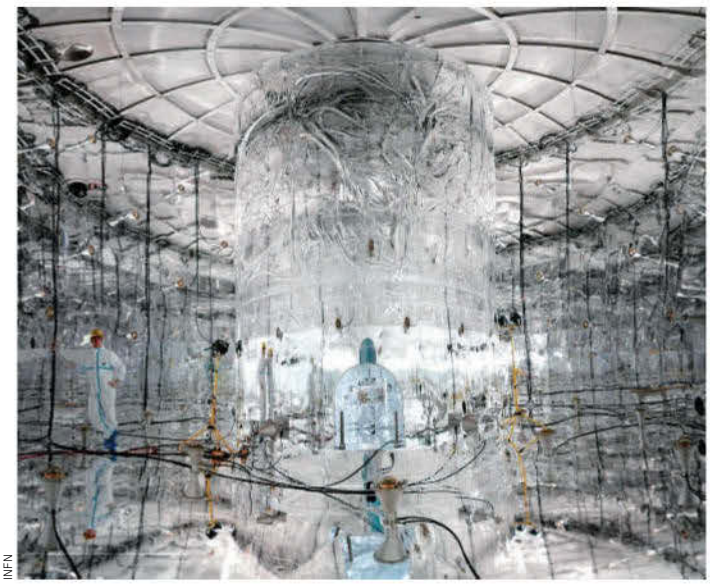
But even that probably won't cut it. Based on our most optimistic estimates for the decay lifetime, we need at least a tonne of detection material to be sure of getting a signal, says Juan Jose Gomez-Cadenas of the xenon-based NEXT collaboration in Spain. That's approaching the limit of what a single experiment can supply, meaning they will need to pool resources. "The wind is shifting from a race to a cooperation," says Gomez-Cadenas.

Researchers on Majorana and GERDA have agreed that if nothing is discovered by 2018, they will join forces to build the first experiment using over a tonne of optimised isotope. That requires at least 10 tonnes of raw germanium that can be purified – almost 10 per cent of the annual global supply, which would otherwise go to technology companies to use for building faster computer chips. But even if a decay is spotted in one isotope, it will need to be confirmed in another. And with the discovery of neutrinoless double beta decay widely tipped to be a Nobel in waiting, researchers will need to guard against overenthusiasm. In an attempt to prevent bias, researchers on the Majorana experiment will conduct a blind analysis, says Elliott, who is the spokesperson for the project. "We analyse only a small amount of data and the rest is locked in the box until an agreed time."

Even if such an analysis proves the decay does exist, this alone won't be enough to prove that Majorana neutrinos are responsible. More complex mechanisms could also be causing this rare decay, with some undiscovered particle taking the role of the neutrinos.

Distinguishing between such mechanisms isn't easy, but new experiments are soon to add to physicists' arsenal – including KATRIN, under construction in Germany, which aims to establish the masses of the three fundamental neutrinos once and for all, and DUNE in the US, which will determine which mass goes with which flavour. If neutrinoless double beta decay is indeed caused by Majorana neutrinos, says Rodejohann, physicists can use the data from these experiments to calculate a lifetime for the process. They can then see if these results match those from direct searches. "If they don't, something else causes neutrinoless double beta decay – that would be fascinating and spectacular."

Huge experiments are needed to detect this rare radioactive decay



INFN

And that could be a valuable result indeed. Such mechanisms are predicted by a host of theories now being searched for directly at CERN's Large Hadron Collider, including some variants of supersymmetry – a favoured route to unifying the fundamental forces.

Yet, especially in physics, the simplest solutions often turn out to be best – and another thing Majorana neutrinos have going for them is that they could settle the thorny questions of why neutrinos are so light.

Most fundamental particles get their masses via the Higgs field, an all-pervading field whose existence was proved in 2012 by the discovery of its associated particle, the Higgs boson. But the vanishingly low masses of the neutrinos suggest that these particles barely interact with the Higgs field at all. That has led some physicists to believe another mass-generating mechanism must be at work.

> "Such a discovery would be more fundamental than the long-awaited sighting of the Higgs boson"

The most popular of these suggests that neutrinos actually come in two varieties – the light ones that pass through us every day, and a heavier partner that far outweighs any of the other fundamental particles. This places the two kinds of neutrinos atop a highly unbalanced cosmic see-saw, with the ultra-heavy family members on one side responsible for bringing down the masses of≈their lighter cousins on the other.

The heavier neutrinos would have decayed in the first instances of the universe and would≈be far too heavy for any conceivable experiment to resurrect, leaving only the lighter variety behind. It's a mathematically elegant solution that is predicted by the vast majority of "grand unified theories" – but it only works if the neutrino is a Majorana particle. In other words there can't be a separate and distinct antineutrino.

Whether the next generation of detectors strengthens the case for a Majorana neutrino or not, they will bring us a step closer to understanding the weird and wonderful processes neutrinos are involved in. And Biller believes this unassuming particle could hold the key to some of the biggest questions in physics. "From lots of perspectives neutrinos look like oddballs, so you've got a good chance of finding something strange." Let's just hope we don't have to wait until the end of the universe to find it. ■

Matthew Chalmers is a freelance writer based in Bristol, UK

HANGING TOUGH

They harbour some of the deadliest viruses, but bats might just hold the secrets to improving human health and longevity, finds **Anthony King**

167/JOEL SARTORE/OCEAN/CORBIS

Roosting jam-packed together increases the spread of pathogens

EMMA TEELING loves bats. She is so keen on them that she has spent the past three summers clambering around Gothic churches in Brittany searching for greater mouse-eared bats under dusty eaves and in dark bell towers. She is aware that others do not share her passion. Bats have been demonised throughout history and across cultures. For most of us, Teeling's little furry fliers are the crepuscular creatures of folklore, witchcraft and horror stories.

Indeed, the dread instilled by bats has only increased in recent years, with the discovery that they harbour the viruses that cause Ebola, SARS, MERS and other so-called emerging infectious diseases. Often fatal in humans, an outbreak of any of these is likely to cause widespread panic – and bats have paid the price. Although they rarely spread these pathogens directly to humans, whole bat colonies are being killed in the name of public health. But where some see a problem, Teeling, a geneticist at University College Dublin in Ireland, sees an opportunity.

The thing is, bats are weird. They don't just carry headline-grabbing viruses, they are also renowned for the huge number and diversity of pathogens they host. In other mammals these would result in sickness or death, but bats hardly ever succumb to viral diseases. They almost never get cancer, too. In fact, they generally live between three and 10 times longer than other mammals of their size – one male Brandt's bat tagged in Siberia in 1962 was recaptured 41 years later, still sprightly enough to catch prey and dodge predators. In the past, researchers have put these peculiarities down to bats' hibernation, a type of suspended animation in places with few predators, and usually at chilly temperatures not ideal for virus replication. Now Teeling and others have found something far more surprising going on. As a result, they believe bats hold secrets that could not only improve our health but also help us live longer.

With more than 1200 species, bats are one of the most diverse groups of mammals – second only to rodents – so it's hardly surprising that they carry many different pathogens. But diversity alone cannot explain why almost every family of virus has been found in bats. Their habit of roosting in large, dense colonies and the ability to fly long distances also play a part. "The way bats live in terms of their mixing patterns and life history will contribute to the way viruses persist," says epidemiologist James Wood at the University of Cambridge, who found that bats host more viruses per species than rodents.

What's really extraordinary, however, is their ability to live with viruses. Working in Ghana, Wood found that between 60 and 80 per cent of fruit bats aged 10 years and older had antibodies for lyssavirus, indicating that they had been in contact with the pathogen, which causes rabies. Nevertheless, the bats were in rude health. The same is true for bats carrying Ebola virus. Kate Baker at the Wellcome Trust Sanger Institute in Cambridge, UK, studied fruit bats in West Africa before the latest Ebola outbreak. In common with many bat species, fruit bats live jam-packed in huge colonies of perhaps a million individuals – perfect for passing on viruses. They can also fly thousands of kilometres, delivering viruses to kin as far away as Uganda and Tanzania. Yet one bat studied by Baker's group lived with Ebola virus for more than a year, showing no ill effects. What is their secret?

Living with the enemy

It's well known that pathogens tend to become less virulent as they coexist with a host over millennia of evolution. But there seems to be something more going on here. Virologist Linfa Wang at Duke-National University of Singapore found one clue. He spent almost two decades in Australia studying flying foxes and Hendra virus, which can jump to horses and then humans, in whom it is often fatal. Around 30 to 70 per cent of these bats in any given colony had antibodies to the virus – revealing they had been infected in the past – with some 3 per cent carrying the virus at any given time. However, the infected individuals had very low levels of the pathogen, indicating they were able to keep it at bay. This probably explains why Hendra very rarely jumps from bats to horses. "It is purely contained by a threshold of virus levels in bats," says Wang. This might be true for other bat viruses too, and could explain why, during the recent Ebola outbreak in West Africa, amid thousands of human-to-human transfers, there was just one presumed bat-to-human transfer.

You could say that, compared with other animals, bats have a more proportional response to viruses – a live-and-let-live approach. They certainly defy the textbook response to pathogens. Research published last year highlights this. Injecting animals with bacterial toxins normally triggers an immune fight-back in mammals. However, the bats had no fever and no spike in white blood cells – two telltale signs that the immune system is launching an attack – although they did lose some body weight. ›

UNLIKELY HEALERS

BATS ARE NOT THE ONLY UNLOVED ANIMALS WITH DISEASE-BUSTING POTENTIAL:

- Pit viper venom was the original source of ACE inhibitors, which alleviate high blood pressure. Tirofiban, a drug taken following minor heart attacks, is also derived from viper venom.

- A cocktail laced with parasitic whipworms is used to treat bowel disease. Intestinal worms help regulate the immune system of their host, and "talk" to friendly gut bacteria – to their benefit and ours.

- The deathstalker scorpion paralyses its prey with venom containing chlorotoxin. This can also latch on to aggressive brain cancers allowing earlier diagnosis and guiding antitumour agents to their target.

- Applying maggots to diabetic ulcers reduces the need for amputation because they clean up the wound by eating dead cells.

- The naked mole rat may hold a cure for cancer. Its secret seems to lie in a large sugar molecule called hyaluronic acid, which gives their tissues shape but is also thought to build a protective cage around individual cells that keeps tumours at bay.

- Venoms from centipedes and duck-billed platypuses are being explored as possible sources of drugs to relieve chronic pain.

"We shouldn't fear bats because the viruses they carry hardly ever transmit to humans"

Wang has found this too. "When you infect bats with a virus, almost uniformly it is hard to make them sick. They don't even have a fever," he says. What's more, give bats tumour-causing drugs and they are far less likely to develop cancer than other mammals. "Bats carry a lot of viruses and that might explain their ability to carry tumours. Without doubt, they are interrelated," he says.

In an attempt to find out what's going on, Wang and his colleagues compared the genomes of two species of bat – a fruit bat and an insect-eater – with those of other mammals. They discovered that genes involved in DNA repair have been reconfigured during bat evolution. "They are very efficient at dealing with DNA damage," says Wang. He notes that key genes in DNA damage repair are also involved in tumour development and immunity. But that's not all – bats have also lost an entire branch of the immune system made up of inflammasomes, receptors and sensors that induce inflammation. In other words, they have evolved to turn down their inflammatory response to various threats, including infection by viruses.

Wang believes the key to understanding these evolutionary changes is flight. Bats are the only mammals capable of powered flight, which is demanding in terms of energy and tough on metabolism. A bat's heart can beat over 1000 times a minute. When in the air, their metabolic rate increases some 34-fold, compared with an eight-fold increase in exercising rodents. This ramped up metabolism spews out free radicals – energetic particles that can damage cells, kick-starting inflammation. Bats needed to evolve adaptations to cope with flight. "If they had the same inflammation system as land mammals, they would get sick more easily," says Wang. So their ancestors re-engineered the system to cope with the harmful metabolites produced by flying and this, in turn, allows them to avoid overreacting to viral infections.

Support for the idea that flight has fundamentally changed bat physiology comes from their mitochondria – the cellular powerhouses. DNA comparisons reveal that bat mitochondria have undergone more evolutionary changes than mitochondria in other mammals. Intriguingly, individual bats have an assortment of mitochondria, rather than carbon copies as most other organisms do. And bat mitochondria seem to have evolved mechanisms to help them mop up the damaging free radicals produced during flight, which researchers at Princeton University think could explain their long lives, tumour avoidance and more. Others, including zoologist Thomas O'Shea at the US Geological Survey, have speculated that bats' revved-up metabolism allows them to raise their temperature and power a faster immune response, a sort of daily fever. "[This] might promote natural selection for the evolution of lower virulence in viruses," he says.

Bats aren't to blame

There's still plenty to be discovered. To that end, last summer Teeling took blood and wing samples from the church bats to track genes and gene expression as bats age. She should be able to tell whether gene regulation becomes gradually disrupted as it does in other animals. If not, that might help explain bats' exceptional longevity. Teeling believes such knowledge will lead to the development of drugs to improve human health and lifespan. Alternatively, she says, we could use new gene-editing technology to make the human genome a little more like that of bats.

Wang is keen to know more too. At his lab, researchers are trying to identify the proteins bats use to control inflammation and other processes associated with disease. These proteins, or versions of them, might one day help to treat disorders where inflammation is a problem – everything from rheumatoid arthritis to heart disease. They could also help stop viruses such as MERS and Ebola from

STEPHANIE JACKSON/AUSTRALIAN WILDLIFE COLLECTION/ALAMY

PHILIPPE PSAILA/SPL

LYNN JOHNSON/NATIONAL GEOGRAPHIC CREATIVE

Testing bats in Africa for Ebola virus (left) and in Australia for Hendra virus (right) reveals that many carry pathogens but few succumb to them

killing us. "There is a cliché in the infectious disease field," says Wang. "Few viruses kill humans. Usually humans kill themselves, because of excessive inflammation."

Closer scrutiny of bat mitochondria also holds promise for therapeutics. Textbooks describe mitochondria as power generators, but increasingly researchers view them as crucial command centres. "Mitochondria are involved in sensing and deciding whether a cell should fight or self-destruct," says Wang. "We propose looking at bat mitochondria to see what's unique about them."

Despite such enthusiasm, not everyone thinks bats are so extraordinary. Birds are also long-lived, and one theory suggests this is because evolving flight enabled them to evade predators, increasing their chances of living to old age and making it worthwhile to invest in costly mechanisms to reduce cellular damage. The same thinking applies to bats. As for the diversity of viruses they host, that could simply reflect bat diversity, says Tony Schountz, an infectious disease specialist at Colorado State University in Fort Collins. Rodents host at least 15 deadly types of hantavirus, he says. And he wagers that if rodents were scrutinised as bats are, we would find lots of new dangerous viruses in them. Bat conservationist Merlin Tuttle agrees. "Virologists often survey hundreds of bats but few other creatures," he says. "Colonial bats are the easiest mammals on the planet to catch in large numbers. I invented the trap most virologists use," he adds ruefully.

An unusual immune system helps flying foxes live with viruses

Schountz believes that any deadly jumps of viruses from bats to people can be explained by humans encroaching on bat habitat and eating bushmeat, and by the movements of domesticated animals. "These viruses have been circulating in bats for hundreds, thousands or perhaps millions of years," he says. "They are only new to us." Tuttle also fulminates against the term "emerging infectious disease" as misleading and a PR disaster for bat conservation. These are exceptionally rare diseases, not sinister "emerging" pandemic catastrophes, he says. And bats are unfairly blamed. The recent outbreak of MERS, first detected in the Middle East in 2012, was initially blamed on bats but later traced to camels. There is no proof of bats having passed Ebola to people either, he says. Yet these remarkable mammals, which have lived alongside us since prehistoric times, are suffering from the stigma of being disease-ridden. "I routinely talk to people who destroyed large bat colonies out of fear of bat diseases," says Tuttle.

Wang, too, despairs of wanton bat killing. But he is emphatic that bats are unusual. "In the last few decades, the high-profile emerging diseases, especially the highly lethal ones, happen to pop up in bats." He has no answer as to why this is so, but believes we should not be afraid of bats because the viruses they carry hardly ever transmit to humans. In fact, he says, trying to control emerging diseases by killing bats may be the worst thing we can do, because any remaining bats will be more stressed, and this seems to raise their virus loads, increasing any risk of spillover to other animals. This may explain why in Queensland in 2011, Hendra virus made multiple leaps out of flying foxes into horses, with a steep spike in outbreaks and 24 cases. Although Wang cannot say what stressed the bats, he did note a surge in the levels of Hendra and other viruses they were carrying.

Far from fearing bats, we should welcome them, says Teeling. "Bats have been demonised and misunderstood." Their nocturnal habits and use of echolocation make them unsettling, almost alien creatures to us, but they are intriguing mammals. "The grassroots conservation organisation I work with in Brittany shows people live bats and they are always shocked at what beautiful furry creatures they are, once seen up close," she says. They are also useful. Many eat insects and one colony can consume tonnes of crop pests in a single night. Now, it turns out, they could teach us how to live longer, healthier lives too. Teeling is confident that it's only a matter of time before this research yields therapeutic rewards. "It's simple. Mother Nature has the answer," she says. ■

Anthony King is a writer in Dublin, Ireland

Star *power*

A global contest is under way to tap the sun's energy from orbit. Is this the start of a second space race, wonders Paul Marks

PG&E, one of the world's biggest utilities, has an unusual deal on its books.

It has pledged to buy all the solar power produced by a tiny, secretive California start-up. But you won't find these panels laid out in orderly rows across a baking desert – they will be in orbit 36,000 kilometres above Earth. There, they will collect the sun's limitless energy and beam it down to power grids.

This isn't just California dreaming. A surprising number of space solar projects are under way around the world, with some heavyweight backers. China is in on the act, and aims to have prototypes in orbit in the 2020s. Russia has already built a prototype, and Japan is so committed to the idea that it has launched a national space solar programme and plans to have operational satellites by the 2030s. The US Navy and several aerospace firms are interested too. So are we seeing the start of a second space race?

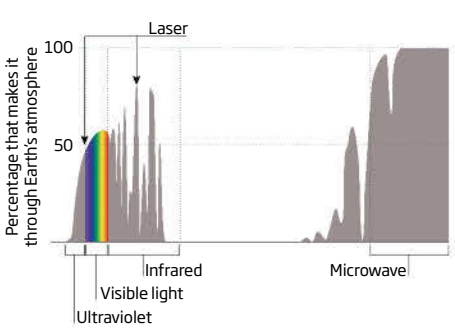
It's not hard to see the appeal. In space, solar power overcomes three obstacles that frustrate terrestrial producers. There are the obvious issues of night and clouds, but also a less discussed problem. Namely, even on the clearest, longest, brightest day, the atmosphere scatters and absorbs the sun's incoming energy until only a fraction of its original strength remains. "How much it's reduced depends on your location," says Paul Jaffe, who is working on space solar modules at the US Naval Research Laboratory in Washington DC. Once through the atmosphere, the power intensity can be anywhere between three and 20 times less (see graph, right).

All three problems go away if you park solar panels in orbit. Out there, vast photovoltaic solar arrays could harvest the sun's undiluted energy almost constantly, offline for just a few hours per year. They would convert this energy to microwaves, which can slice through Earth's atmosphere, rain or shine, sending enough power into terrestrial grids to rival coal and nuclear, but without their environmental drawbacks (see illustration, page 41).

That's the theory, anyway, and it was first proposed by aerospace engineer Peter Glaser in 1968. A decade later, when the oil crisis threatened the US with a future devoid of fossil fuels, NASA and the US Department of Energy collaborated on a $20 million investigation into how to make it work in practice.

Better in space

Earth's atmosphere scatters and absorbs the sun's incoming rays. Some frequencies are totally lost, but others make it through unimpeded

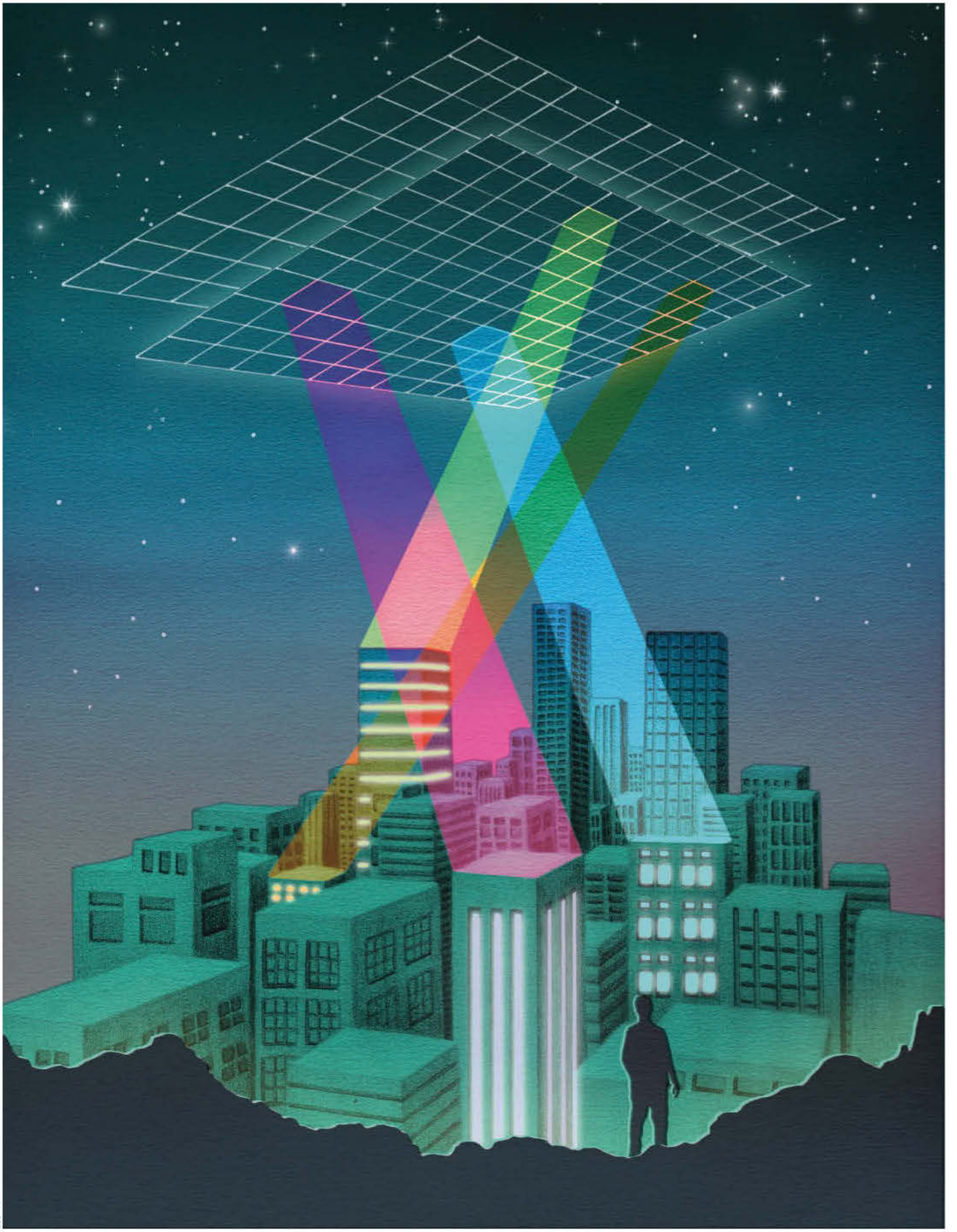


Their findings were not encouraging. Supplying electricity just for the north-eastern part of the US would have required solar panels many kilometres wide, feeding a microwave antenna 2 kilometres across. Built from the technology available at the time, this monstrosity would have weighed 81,000 tonnes. Back when it cost $50,000 to send a single kilogram of cargo into space, the launch costs alone came in at $4 trillion. When the oil crisis ended shortly after, nascent space solar plans were scrapped.

A few decades on, worries about fossil fuels have compelled several countries to take a fresh look at space solar. China, beset with choking levels of fossil-fuel smog, is studying space solar as part of a much larger renewable energy programme. Roscosmos, Russia's federal space agency, has built a small Earth-based prototype.

At the forefront of space solar research, however, is Japan. It makes sense; the country has no fossil fuel resources of its own, insufficient land mass for wind and solar, and the Fukushima nuclear disaster is still fresh in citizens' minds. Japan's space agency, JAXA, along with the Universities of Tokyo and Kobe, as well as Japan Space Systems have developed a rigorous road map for space solar. Orbital tests are scheduled for the 2020s, in readiness for fully operational satellites delivering 1 gigawatt in the 2030s.

These optimistic schedules reflect a growing global consensus that the prospects for space solar are brighter this time around. "It's not like antigravity," says George Whitesides, ›



ESSY MAY

MITSUBISHI HEAVY INDUSTRIES

Even transmitting a few kilowatts wirelessly takes a lot of kit

CEO of Virgin Galactic and a former executive director of the US National Space Society, a space solar advocacy group. "It's just a question of whether you can get it to work, and make sense financially."

They are starting to get it to work, thanks in part to half a century of technological advances. Take wireless power. In 1975, NASA beamed 34 kilowatts to light an array of 300-watt lamps 1.5 kilometres away. By 2008 they had increased the distance more than 100 times, beaming between two islands in Hawaii. A Kobe University project has even beamed power to an Earth-based receiver from space. "The most important thing is not the power but learning how to steer the beam," says Kobe researcher Nobuyuki Kaya. Last year, aerospace contractor Mitsubishi, working with JAXA, set a new record for precision.

Solar cells have also seen steady improvements. Peak efficiencies for the best space-based solar cells crept up from 6 per cent in the 1950s to hover around 30 per cent, says Gary Spirnak, CEO of Solaren, the start-up in Manhattan Beach that's in league with PG&E. "But that's just for one sun," he says. Reflecting the sun's intensity onto them many times over, using dynamic arrays of mirrors, doesn't merely yield more energy from more radiation. "If we can get 400 to 500 suns on them," he says, "their efficiency actually improves to something like 45 per cent."

That still leaves an enormous structure to get into space – unlike solar and wireless technology, launch costs have not improved significantly with time. According to most analyses, they still need to drop by at least two orders of magnitude for space solar to become viable – to $150 per kilogram.

That won't happen in any hurry, so the only other option is to put space solar satellites on a strict weight loss regime. This is what much of the new research is focused on. Last year, the California Institute of Technology in Pasadena teamed up with defence heavyweight Northrop Grumman on a three-year, $17.5 million research programme. The aim is to "attack every aspect of the weight," says Harry Atwater, a photovoltaic materials scientist at Caltech: "the solar energy generation layer, the wireless microwave transmission system and the spacecraft structures".

But reducing launch costs isn't just about weight – it's also a matter of folding the design into as few launches as possible. Kaya says he has found a way to tuck the photovoltaic layer, the electricity-to-microwave conversion electronics and the Earth-facing antenna into one lightweight sliver less than 1 centimetre thick. Similar plans are afoot at Solaren. While Spirnak is keeping details under wraps, he says their satellite will be placed into orbit in as few as three large rocket launches.

And those rocket launches are set to get a

SPACE SOLAR: MYTHS AND REALITIES

WILL IT FRY BIRDS?

Unlikely. This question is probably a hangover from the days when lasers were earmarked as the delivery system for beaming space-generated power to Earth – the vast majority of today's projects aim to use microwaves (see main story).

The most intense sunshine on Earth – a clear, sunny day at the equator – hits you with 1000 watts per square metre. If you were standing at the centre of a 10-kilometre-wide microwave beam from space, it would hit you with one tenth of that, says Paul Jaffe, who works on space solar at the US Naval Research Lab in Virginia. This is the internationally agreed safety limit for people working near microwave frequency fields. The birds will probably be fine, too. A study trained a microwave beam two and half times more intense on a group of birds continuously for 18 weeks. "It showed no harmful effects," Jaffe says.

WILL IT DOWN PLANES?

No. None of an aircraft's instruments operate on the frequencies being considered for space solar transmission. However, passengers' in-flight Wi-Fi might suffer for a few moments as the plane passes through the beam. That's if Kobe University in Japan has its way and space solar transmits via the 2.4 gigahertz frequency. That's not a guarantee – the Japanese Space Agency prefers the industrial 5.8 gigahertz frequency. The final say will go to the UN's International Telecommunications Union, the body that polices frequency allocations. If it chooses the industrial frequency your Wi-Fi will be fine.

WILL IT CHANGE THE WEATHER?

Solaren, a space solar start-up in California, has filed a patent that indicates a microwave beam directed from space onto the eye wall of a hurricane could dissipate its destructive energy. The patent was not granted, but does it suggest that one – or many – directed energy beams could seed clouds or otherwise interfere with the world's weather. Should we worry?

Jaffe thinks not: the frequencies of any future space solar beam will be chosen explicitly to minimise interference with meteorological systems, letting all the energy pass through unimpeded. Otherwise, the beam would be an unreliable power source.

In any case, getting a solar power beam to change the weather, he says, "is probably harder than making a space solar power system, which is already pretty hard".

WILL IT BE USED AS A DEATH RAY?

Could there be geopolitical ramifications for the first nation to beam power from orbit? Would it be seen as an act of war? It will only be a problem, says Jaffe, if an operator opts for laser delivery. "A big laser in space presents more of a weapon threat than a giant radio wave transmitter in space. With microwave beams, the physics works against you," he says. In other words, very weak heating is a very poor weapon.

lot cheaper thanks to another ongoing space race – the race to build reuseable rockets. Several companies are vying for dominance, having demonstrated successful tests. When it is no longer necessary to throw away an entire rocket with every launch, there will be major boosts for space solar's bottom line.

Tracking beam

However, even amid all this optimism, some of the more ambitious programmes have already stumbled. Solaren was originally supposed to start transmitting power this year, but quietly shifted the schedule to 2025. And Japan, which had plans to test a small solar satellite in low-Earth orbit in 2018, now seems to be redrafting its timeline. Is this a temporary hitch or the beginning of another slide back into obscurity?

There's plenty of money on the latter. Some of the biggest criticisms come from Elon Musk, the high-profile founder of commercial space-flight firm SpaceX, and also of solar panel maker Solar City. His objection is that multiple conversions between energy types – solar to electricity, then to microwaves and then back to electricity – is inefficient and will waste power, quashing any advantage gained from a 24/7 power source.

If the steady pace of improvement keeps up, Musk's objection will eventually be resolved. John Mankins, a physicist and NASA veteran who now advocates for space solar, doubts that such setbacks will keep nations like Japan, at the mercy of imported energy prices, from driving the technology forward. Then there's climate change. Unlike the oil crisis of the 1970s, it's not going away.

The Paris Agreement aims to hold anthropogenic warming to "well below" 2 °C. Most climate scientists agree that existing technologies probably won't get us there. Transformative technologies are needed, says Mankins.

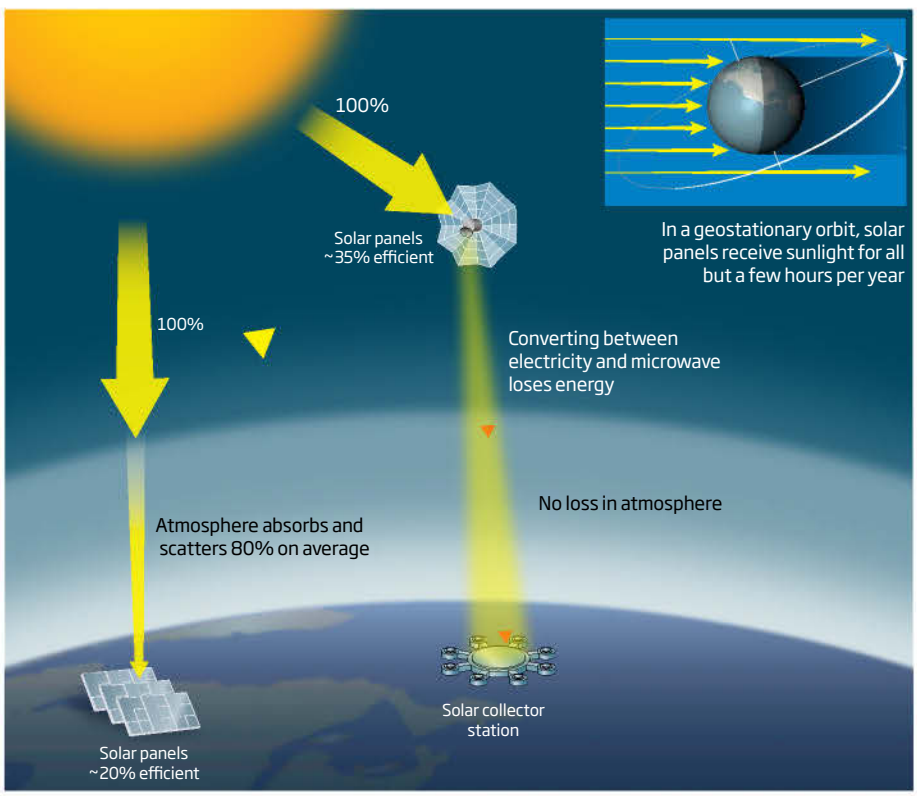
A more damning objection is whether space solar can even produce useful amounts of power. Most entities pursuing space solar have chosen 1 gigawatt as their goal. But even if one massive satellite can provide that, the number pales compared with existing solar generation capacity in the US, which exceeds 1000 gigawatts.

However, Mankins says 1 gigawatt is just the start. His estimates suggest the satellites can be scaled up to 10 gigawatts each.

What's more, Glaser's original plans had the satellites in geostationary orbit, hovering above the same spot on Earth's surface to make beaming power as simple as possible. But there is no reason to keep them confined to an increasingly crowded orbital belt. Equip them with widely available beam-steering equipment, and they could spread into the wider area of geosynchronous orbit. Here, they would need to adjust their beam to keep it trained on the receiver back on Earth. This would add cost, but makes room for 1000 satellites. The long-term potential of space solar now climbs to 10 terawatts – more than half of Earth's present capacity.

Full beam

Building solar farms in space can help the technology overcome three main problems that plague solar power on Earth: night, weather and atmospheric absorption



> **"Whoever gets space solar to work will be the Saudi Arabia of clean energy"**

But Jaffe wonders if comparison with nation-scale energy supply misses the point. Beamed continuously 24 hours a day, space solar will never need to be stored, eliminating batteries. And a beam that can be sent anywhere in the world can deliver power to places without transmission lines. That's an attractive prospect, albeit only for high-end niche concerns to start with. US navy ships, for example, are becoming floating data centres, so the organisation is keen to find alternative ways to provide them with extra power. Tracking a ship with an orbital power beam fits the bill.

And that's just on Earth. Using lasers to transmit power would be dangerous for terrestrial applications (see "Myths and Realities", far left), but it opens up a wealth of possibilities in space. JAXA thinks they could be useful for beaming power from one spacecraft to another, or from space to the moon. There aren't many other options for getting power to asteroid mining and lunar operations.

Whatever the killer app, Jaffe says, the first successful demonstration of the technology will likely spark a new space race. "Whoever gets this technology to work first," he says, "becomes the Saudi Arabia of clean energy."

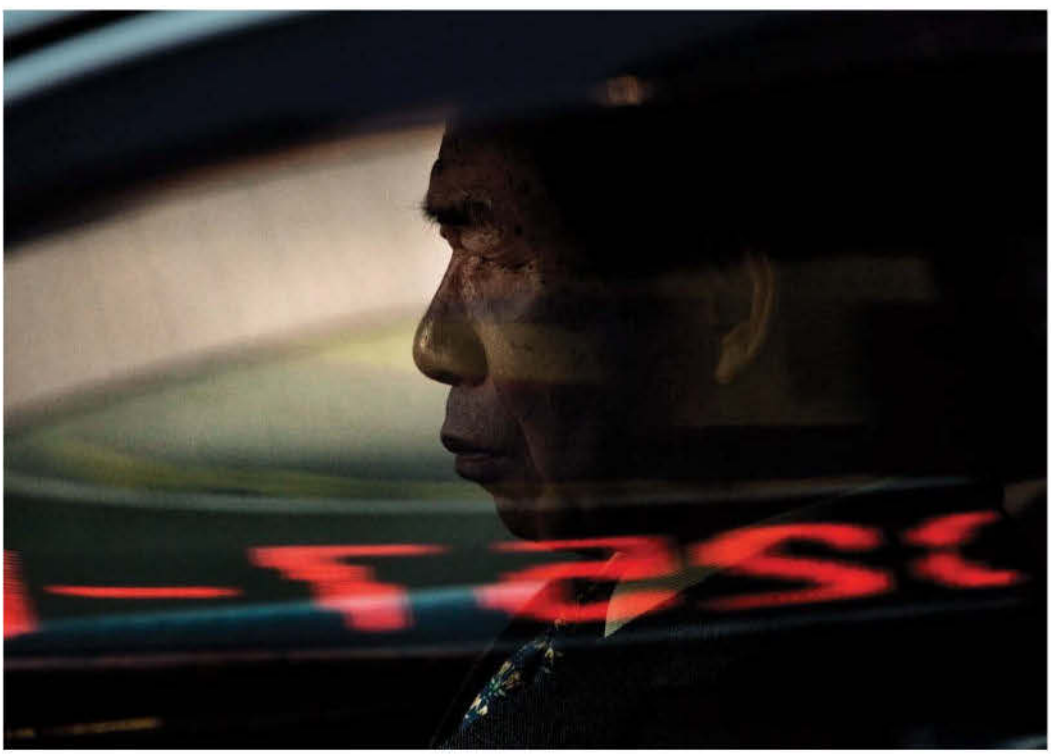
No wonder California wants in. ■

Paul Marks is a technology writer based in London

The brain's deep secret

We are beguiled by the unconscious, finds **Anil Ananthaswamy**

NeuroLogic: The brain's hidden rationale behind our irrational behavior by Eliezer Sternberg, Pantheon, $28.95



PAOLO PELLEGRIN/MAGNUM PHOTOS

Habit of mind: Driving a route daily becomes mostly automatic

"THE conscious mind may be compared to a fountain playing in the sun and falling back into the great subterranean pool of subconscious from which it rises," wrote Sigmund Freud. For him, the unconscious/subconscious (he used the words interchangeably at first) played an outsized role in governing human behaviour. We are enthralled by the idea that we aren't privy to most of the mental processes that make us human.

In 2016, the idea of the unconscious mind is still enthralling, but in a very different way. The neurology and cognitive science that has replaced psychoanalytical notions with evidence-based ideas demands constant revision and is nuanced and complex. So any book trying to bring us up to speed must do so with restraint, even as it attempts to excite and entertain.

Eliezer Sternberg, a neurologist at Yale-New Haven Hospital, has a stab at elucidating the power of the unconscious from the scientific perspective of the 21st century. In *NeuroLogic,* he tells us where we are now: "The unconscious system in the brain pieces together fragments of our perceptions, anticipating patterns and filling in gaps when necessary… to devise a single, meaningful interpretation. It tells a story. The conscious system experiences that story but can also reflect on it and question it."

Understandably, Sternberg focuses mainly on conditions that give rise to seemingly irrational perceptions and behaviours, but which make sense in terms of a compromised unconscious. For example, people who are fully or partially blind can sometimes experience vivid visual hallucinations. This is Charles Bonnet syndrome, where the visual cortex can occasionally become active despite a lack of signal from the eyes, possibly because neural signals "leak" in from other brain regions.

For avid readers of popular neuroscience, much of this will be familiar as Sternberg dips into a grab bag of neurocuriosities. Those newer to the field will be intrigued, say, by blindsight, in which someone unconsciously responds to a stimulus while denying having seen it, or alien hand syndrome, where damage to the brain's frontal lobe can result in losing control over the actions of, say, your right hand.

For me, as a relatively informed reader, the most intriguing part of *NeuroLogic* is when Sternberg writes about how consciously learned behaviour can become habitual: "There are two parallel systems in the brain that control behavior. When we practice a behavior enough, we can automate it, allowing the habit system to take over. This frees up the conscious, non-habit system to focus on something else." For example, the complex activity of driving a car requires vision, touch and exquisite motor control. But it can become mostly unconscious when the driver takes the same route day after day.

Why did both the conscious and unconscious systems evolve? Sternberg doesn't say so explicitly, but his way of delineating brain activity suggests one reason we may have evolved consciousness: to shoot down illogical stories concocted by the unconscious – which he calls an "egocentric storyteller" – that can get things wrong when the neural circuitry goes haywire.

Can the conscious right some of these wrongs? Can it influence the

unconscious? Yes, says Sternberg: "Mental simulation is a means by which the conscious system can change the unconscious system." Take the British athlete Steve Backley, a bronze medallist in the javelin at the 1992 Barcelona Olympic games, who sprained his ankle just before the 1996 Atlanta games. He was on crutches for weeks, so he trained by imagining the perfect throw over and over again. He won silver that year.

NeuroLogic sometimes feels like a series of well-written magazine articles, drawing mostly on academic case studies that are once-removed from real people and their stories. This can make the writing a bit distant, especially when the conditions described are harrowing. But occasionally we get a ringside seat, as when Sternberg describes his friend Ethan's visceral fear on being

"The unconscious system in the brain pieces together fragments to devise a meaningful interpretation"

"attacked" by an imaginary falcon conjured up by a stage hypnotist.

In trying to make his case for the conscious and unconscious, Sternberg sometimes fails to use the nuance necessary to fully grasp complex conditions or neural processes. For example, he omits recent insights into possible neurocognitive mechanisms behind Cotard's syndrome, a disorder in which people think they are dead. And then there are mirror neurons, which studies in monkeys show fire when an animal observes the action of another. Sternberg leaves us with the impression that there is little or no controversy about their existence in humans and about claims linking them to everything from empathy to culture.

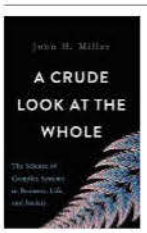
It's a useful reminder that in this fast-moving, complex field, nuance is everything. ■

Anil Ananthaswamy is a consultant for *New Scientist*

What will emerge…

Complexity is still outwitting us, finds **Mike Holderness**

A Crude Look at the Whole: The science of complex systems in business, life, and society
by John H. Miller, Basic Books, $29.99



COMPLEXITY is not just a word for messy stuff. It is a useful label for a set of interesting approaches to understanding it. From climate systems to the question of quite how it is we are conscious of them, we encounter phenomena on a daily basis characterised by large numbers of simple interactions between, say, gas molecules or neurons, that collectively produce behaviour of a different order.

The banking crisis of 2008 showed once more that treating complex systems as if they were determined by simple sums and averages of their parts is a recipe for misunderstanding – or worse. A working understanding of this among legislators and regulators might even have helped make world economic recession less likely.

John Miller, a professor of economics and social science at Carnegie Mellon University and a fellow of the Santa Fe Institute for the study of complexity, seems ideally placed to explain things, at least to the business community.

A Crude Look at the Whole presents most of the starter-level examples of complexity. Social insects are an illustration crucial to Miller's economic focus. He gives an engaging account of how the simple behaviour of individual ants produces something that looks a bit like intelligence in the nest as a whole. (Although the report of a wave of army ants 60 feet wide and 3 feet thick seems to betray a scarcity of editor drones.)

But the fundamental difficulty of a simple account of this field is shown by the lack of interesting and challenging mathematics. Probably wisely, Miller makes no attempt to convey the fun you can have defining the states of a system as points in a "phase space" with 7 billion dimensions. But that's just one of a number of options for modelling the world economy as a collection of individual agents – an interesting task that seems central to Miller's economic concerns.

Nor is there any real discussion of the implications for the philosophy of science. In 1972, the physicist Philip Anderson wrote that "more is different", leading to much discussion of the idea that the behaviour of complex systems is "emergent" from that of their components. That discussion has yet to reach a conclusion about what kind of knowledge, if any, emergence represents. And Miller may have overreached for layperson's language when he writes that "water and stones, then, provide an existence proof that cleverness is not restricted to smart things" – unless he actually does embrace the panpsychic view that all stuff thinks.

In such a field, politics is never far away. There are many undercurrents of conservatism here, for example, when Miller writes that an understanding of the complex behaviour of social networks could help a state that wanted to prevent "rabble-rousers" gaining support. Such an understanding is of even more use to agitators for whom inventing things that the state does not know how to respond to is much to the point.

Miller's conclusion is that "the various proofs, observations, and conclusions that form each thread are beginning to fade into a deeper understanding as we look, in perfect silence, at the complexity that abounds". More research is clearly required to get there in an accessible way or, perhaps, at all. ■

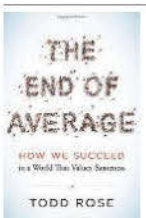
Ants each behave simply, but together achieve clever feats

INGO ARNDT/NATUREPL.COM

The mean standard

Jonathon Keats finds that the concept of average can be damaging

The End of Average: How to succeed in a world that values sameness
by Todd Rose, Allen Lane, £20



IN the early 1940s, an American gynaecologist made an alabaster model of a typical young female by averaging the proportions of thousands of women. The statue, named Norma, was hailed as a physical ideal. Yet when a newspaper ran a contest to celebrate living lookalikes, fewer than 40 of the 3864 applicants even came close to sharing Norma's physique.

Todd Rose has an explanation: "No one is average," he asserts, and averaging distorts the unique mix of attributes found in every individual. In *The End of Average*, Rose makes a strong case against "averagarianism", and attempts to show how an emphasis on individuality can revitalise higher education and the workplace.

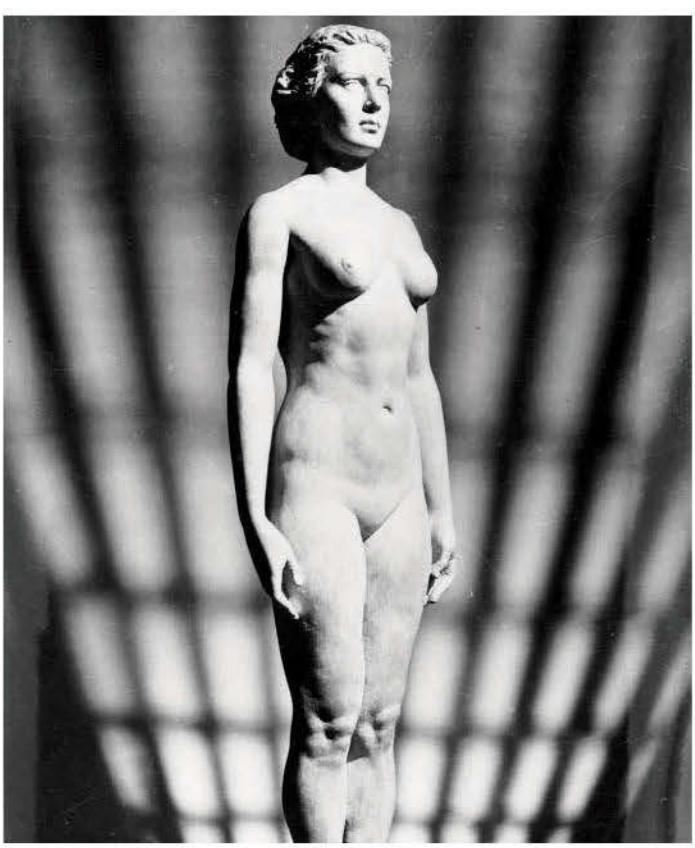
In the latter days of the industrial revolution, an American named Frederick Taylor began measuring the efficiency of workers. For each step of every task, Taylor found that some labourers were more efficient than others. He concluded that there was one best way to get any job done, and mandated that all routines be standardised. The fate of workers was to be decided by comparing their performance to an average.

And if labourers could be systematised, then so could children. Rose shows how Taylorism defined education: standardised curriculums supply a standardised workforce, and grading performance against an average then sorts students for future employment.

These developments had advantages, such as increased prosperity, but Rose believes the price has been steep: "we all strive to be like everyone else, only better… We have lost the dignity of our individuality." Moreover, we've done so based on false assumptions about what averaging can achieve, much as Norma's creator falsely assumed he was showing a typical young woman's physique.

Rose presents three reasons why nobody is average. The first, the jaggedness principle, derives directly from the Norma lookalike competition. For any given measurement, such as height or breast size, matches would have been abundant. However, because height and breast size aren't correlated, women who matched the average breast measurement were likely to be taller or shorter than Norma. Any one-dimensional ranking based on averaging multiple unconnected qualities will suffer from this defect, a problem Rose identifies in ratings of talent and intelligence.

"We all strive to be like everyone else, only better. We have lost the dignity of our individuality"



No real human can live up to a precisely average woman

THE CLEVELAND MUSEUM OF NATURAL HISTORY

Rose's second principle takes context into account. Citing research on children's behaviour in summer camps – where a child might be honest with friends but lie to counsellors – he argues that each person has a unique set of behavioural "if-then signatures", which are more meaningful than any overarching characterisation.

Finally, there's his pathways principle, which attacks the very core of Taylorism. Many tasks, such as learning to walk and learning to read, have been shown to have equifinality: diverse approaches achieve equivalent results. There's no best way to learn and no best career path. For most, the average way of doing anything will be less than ideal.

Although none of these insights is especially profound, Rose's book is a cogent rebuttal of assumptions about averageness.

He's far less effective in offering alternatives. His suggestion that industry embrace individuality is limited to a few anecdotes (and much praise for Google's HR department). His approach to individuality in education is more flimsy still, leaning heavily on massive open online courses without addressing their dismal completion rates. More disturbing, Rose operates from the Taylorist premise that school is about "career preparation".

Whatever happened to entrepreneurship? Whatever happened to opting out entirely? ■

Jonathon Keats's new book on the legacy of Buckminster Fuller, *You Belong to the Universe*, is out in April

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Grant Programs

BIOMEDICAL SCIENCES

Career Awards for Medical Scientists: Five-year awards for physician scientists provide $700,000 to bridge advanced postdoctoral/fellowship training and the early years of faculty service. This award addresses the on-going problem of increasing the number of physician scientists and will help facilitate the transition to a career in research.

Collaborative Research Travel Grants: Provide up to $15,000 in support for interdisciplinary biomedical researchers from degree-granting institutions to travel to a laboratory to acquire a new research technique or to facilitate collaboration.

DIVERSITY IN SCIENCE

Postdoctoral Enrichment Program: Provides $50,000 over three years to support the development of underrepresented minority postdoctoral fellows in biomedical research.

INFECTIOUS DISEASES

Investigators in the Pathogenesis of Infectious Disease: Five-year awards provide $500,000 for opportunities for accomplished investigators at the assistant professor level to study infectious disease pathogenesis, with a focus on the intersection of human and microbial biology. The program is intended to shed light on the overarching issues of how human hosts handle infectious challenge.

INTERFACES IN SCIENCE

Career Awards at the Scientific Interface: Five-year awards provide $500,000 to bridge advanced postdoctoral training and the early years of faculty service. These awards are intended to foster the early career development of researchers with backgrounds in the physical/mathematical/computational/engineering sciences whose work addresses biological questions. BWF has moved to a self-nomination format for this award.

POPULATION AND LABORATORY BASED SCIENCES

Institutional Program Unifying Population and Laboratory Based Sciences: Five-year awards provide $2.5 million to unite population-level and laboratory-based biological sciences. The award supports the training of researchers working between existing research concentrations in population approaches to health and in basic biological sciences. The goal is to establish interdisciplinary training programs by partnering researchers working in disparate environments and intellectual frameworks.

REGULATORY SCIENCE

Innovation in Regulatory Science Awards: Provides up to $500,000 over five years to academic investigators who are addressing research questions that will lead to innovation in regulatory science, with ultimate translation of those results into improving the regulatory process. These awards are intended to provide support for academic researchers developing new methodologies or innovative approaches in regulatory science that will ultimately inform the regulatory decisions the Food and Drug Administration (FDA) and others make.

REPRODUCTIVE SCIENCE

Preterm Birth Initiative: Provides $600,000 over a four-year period to bring together a diverse interdisciplinary group with the more traditional areas of parturition research to address the scientific issues related to preterm birth.

SCIENCE EDUCATION

Career Awards for Science and Mathematics Teachers: Five-year awards provide $175,000 to eligible science or mathematics teachers in the North Carolina public primary and secondary schools. The purpose of this award is to recognize teachers who have demonstrated solid knowledge of science or mathematics content and have outstanding performance records in educating children. The award is a partnership between the North Carolina State Board of Education and BWF.

Student Science Enrichment Program: Three-year awards provide up to $180,000 to North Carolina nonprofit organizations, including public/private schools, universities, colleges, and museums. This program supports creative inquiry-based science enrichment activities that occur outside the typical school day for K-12 students. The program's goals are to nurture students' enthusiasm about science, expose them to the excitement of scientific discovery, and interest them in pursuing careers in research or a variety of other careers in science.

Promoting Innovation in Science and Mathematics: Awards provide teachers with funding for materials, equipment, and training to conduct hands-on, inquiry-based science and mathematics projects in North Carolina public schools.

The Burroughs Wellcome Fund is a private foundation located in Research Triangle Park, North Carolina. Find out more at **bwfund.org**

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Science Program Leader
National Eye Institute

The National Eye Institute (NEI), a component of the National Institutes of Health (NIH) and the Department of Health and Human Services (DHHS), conducts and supports research, training, health information dissemination, and other programs with respect to blinding eye diseases, visual disorders, mechanisms of visual function, preservation of sight, and the special health problems and requirements of the blind.

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The Science Program Leader will have responsibility of providing guidance and leadership in translating nonclinical findings to clinical testing. This incorporates a large and broad arena of expertise and capabilities including: (1) a strong fundamental background in basic science research to generate a compelling data package to convince the FDA and other regulatory agencies (internal and external) to advance an investigational agent to human testing (2) a comprehension of the regulatory requirements to plan, design, execute, interpret, and report Good Laboratory Practice (GLP)-compliant toxicology studies; (3) the knowledge required to assure a well-written and appropriately designed clinical protocol; (4) to ensure high quality synthesis, production, and testing of clinical grade material for Phase I testing in compliance with FDA gene therapy regulations; (5) operational skillset to work with individuals of diverse backgrounds including scientists, engineers, clinicians, pharmacists, individuals with legal and regulatory expertise internal and external; (6) ability to define, manage, and implement plans/programs to attain goals on time; and (7) experience in working with biologics and the Center of Biologics Evaluation and Research (CBER) division of the FDA.

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SALARY/BENEFITS: The salary for this position will be commensurate with qualifications and professional experience. A recruitment or relocation bonus may be available, and relocation expenses may be paid. A full package of Federal Civil Service benefits is available, including: retirement, health and life insurance, long term care insurance, leave, and a Thrift Savings Plan (401K equivalent).

HOW TO APPLY: Submit a current curriculum vitae, bibliography, and full contact details for three references. In addition, applicants are asked to prepare a statement that addresses the specific qualification requirements (please limit the statement to no more than two pages). Send application package to Cynthia Best at bestc@nei.nih.gov.

NEI will begin accepting applications February 15, 2016 and plans to have the position open for 30 days.

Information about NEI can be found at NEI.NIH.GOV

You may contact Cynthia Best with questions and for more information about this vacancy on (301) 496-2234.

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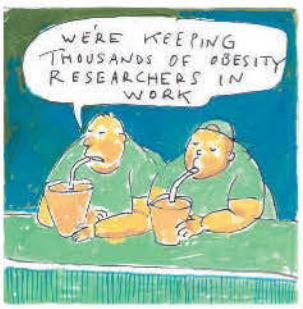
EDITOR'S PICK



The sweet side of a sugar tax

From Patrick Bradley

Tom Sanders expresses scepticism about the likely impact of a sugar tax on obesity and related health problems in the UK (16 January, p 26). It is true that in Mexico, the direct impact of the sugar tax on calorie intake appears to be small. But sugar has an impact on calorie intake beyond its own caloric value.

The increase in US obesity rates after the 1960s followed a 500 per cent increase in the consumption of sugary drinks and a 150 per cent increase in sugar added to processed foods.

A recent study of minority US adolescents found that consumption of sugary drinks was associated with decreased satiety and depressed levels of the hunger-regulating hormone ghrelin.

Consistent with these results, a survey of 75 countries from 1997 to 2010 found that a 1 per cent rise in soft drink consumption was associated with an additional 2.3 obese individuals and 0.3 diabetic individuals per 100 adults.

So a soda tax seems certain not only to make a significant impact on obesity-related ill health but also to boost government revenue.

Wollongong, New South Wales, Australia

The editor writes:

■ **For more on how sugar affects satiety, read our "gut thinking" feature (21 November 2015, p 30).**

The tale of the secret telescope

From Guy Cox

Nigel Henbest alludes to Chester Moor Hall's invention of a lens with little chromatic aberration (19/26 December 2015, p 73). There is more to it than he recounts.

As Henbest reports, around 1729 Hall worked out that he could make an achromatic lens by combining a strong positive lens of crown glass and a weak negative one of flint glass. Hall was paranoid that whoever he asked to make these lenses would steal his idea, so he commissioned each lens from a different optician.

Unfortunately, they both subcontracted the job to the same man: George Bass. Bass worked the principle out immediately but kept the secret. He duly made the lenses and built Hall a telescope around them in 1733. It still exists.

Bass and Hall made several more achromatic telescopes, which impressed astronomers of the day, but the technique remained secret for 20 years. Then Bass discovered that John Dollond was working along similar lines and revealed the formula. Dollond promptly patented it, which naturally led to a lawsuit.

The judge ruled that although Hall's priority was clear, he had had 20 years to do something about it, so Dollond deserved patent protection for bringing the idea to market. Dollond's achromatic telescopes were available from about 1758.

Sydney, Australia

Self-driving cars on the starting grid

From Jan Kowal

You quote transport researcher Steven Shladover as saying that the limitation on an urban traffic grid is the time it takes vehicles to start moving when a traffic light changes to green (23 January, p 21). He thinks that this is something autonomous cars don't improve.

It is a familiar experience for drivers to be several cars back from the lights and, once they have changed, to have to wait seconds before being able to move, as other drivers must realise that the car in front has set off before moving themselves. I would have thought this is exactly where autonomous cars would help: they could all move off in unison, maintaining the much shorter stopping distance possible with vehicle-to-vehicle communication.

Oxford, UK

From Chris James

Self-driving cars will make gridlock worse because, as well as cars with people in them, there will be empty ones on the move whereas cars with drivers would have to be parked somewhere.

Winchester, Hampshire, UK

The editor writes:

■ On one hand, yes, the empty cars will have to go somewhere. But on the other, driverless cars could mean that employees who drive to work – the main cause of gridlock – are dropped off by a car that then whizzes off to pick up other people.

Deeper reasons for keeping archives

From Richard Epworth

Karin Ljubic Fister discusses storing data in plant DNA (16 January, p 27). Archiving addresses two different scenarios.

In the first, we want to preserve information for future humanity. A second deals with the case of "intelligent" humans being absent through bombing ourselves back to the Stone Age, or extinct due to climate change, for instance.

Assuming we do not sterilise our planet, encoding an enduring archive in the DNA of something with a long history of endurance, such as bacteria or cockroaches, would make our data available to our successors. Life will then take care of the need for regularly refreshed copies.

Perhaps our own "junk" DNA already carries the archived data of some ancient intelligent species, or evidence for how "we" blew it last time.

Sawbridgeworth, Hertfordshire, UK

More solar system surprises in store

From Richard Miles

It seems to me that the solar system holds more great mysteries beyond the six you highlighted (23 January, p 28). There appears to be a diverse menagerie of objects, notably asteroids and comets, the true nature of which we have only just begun to explore.

Take, for example, one of the largest periodic comets known: 29P/Schwassmann-Wachmann. This strange body occupies a near-circular orbit beyond Jupiter. Since its discovery in photos from 1927, it has displayed energetic outbursts or eruptions between four and eight times a year, powered by some mysterious source yet to be identified.

Stourton Caundle, Dorset, UK

After a quantum-indeterminate past

From Toby Pereira

Joshua Sokol discusses how we define the future as the direction in which entropy increases, and says that we could rewind time to the big bang, when the universe had less entropy (16 January, p 8). But if the laws of physics are time-symmetrical, this must also apply to unpredictable quantum events. So if we were able to run time backwards, things would not have to be the same as they were. If the

"We prefer to go by a 'non-empty subset' of mathematicians, just to make things clear"

Emma Ní Bhéarae makes a precise contribution to the #scienceherdnames search for collective nouns

past is as indeterminate as the future, what right have we to say that a low-entropy big bang is the one correct version of our past?
Rayne, Essex, UK

Does 'fine tuning' have meaning?

From Martin Sahlén
Mary-Jane Rubenstein writes that modern physics considers it strange to find our universe so hospitable to life, when nearly any other values for the fundamental constants would not have allowed life to form (19/26 December 2015, p 64). A proposed solution to the problem is offered by a multiverse containing many different values of physical constants.

While this is a fair description of contemporary debates in physics, the fact is that we don't know whether there is any meaning to the notion of "fine-tuning" of physical constants. Indeed, if there is only one universe, in what sense can we give meaning to the notion of "fine-tuning of constants"?

An empirical approach fails, because there are no other universes to observe for comparison. A probabilistic approach fails because, at the level of the universe as a whole, probability is not well defined, nor can it be empirically verified.

Whatever we may mean by fine-tuning of constants, it must be rooted in mathematical, aesthetic, philosophical or theological assumptions.

For example, we may be assuming that the mathematical form of physical laws remain fixed when considering alternative values of physical constants. This gives a privileged status to the physical laws that they need not necessarily have.

There is a clear affinity here between modern physics and philosophical-theological inquiry, fertile ground for asking deep questions about chance, necessity, naturalness, meaning, causality, creation and existence.
Uppsala, Sweden

From John Phillips
Within any infinite multiverse there will be many very clever sentient species – biological, machine, and other types not yet conceived of. Some of these will have worked out exactly how the multiverse works and will thus be able to control it.

If just one species decides to destroy the whole thing – and this must happen, due to the infinite possibilities expressed in the multiverse – then our universe also cannot exist. There is, therefore, no multiverse.
Hughenden Valley, Buckinghamshire, UK

Flood prevention scheme vindicated

From Pamela Ross
I was pleased to see a photo of our church on your leader page, standing dry above floodwaters (9 January, p 5). It illustrates the success of our local flood alleviation scheme.

This was put in place in the mid-1980s on behalf of British Coal during the sinking of the coal mines in its Selby Complex. It has kept the majority of the village dry since then. Alternately higher and lower river banks mean that water flows over the lower banks into selected fields and the villages stay dry.

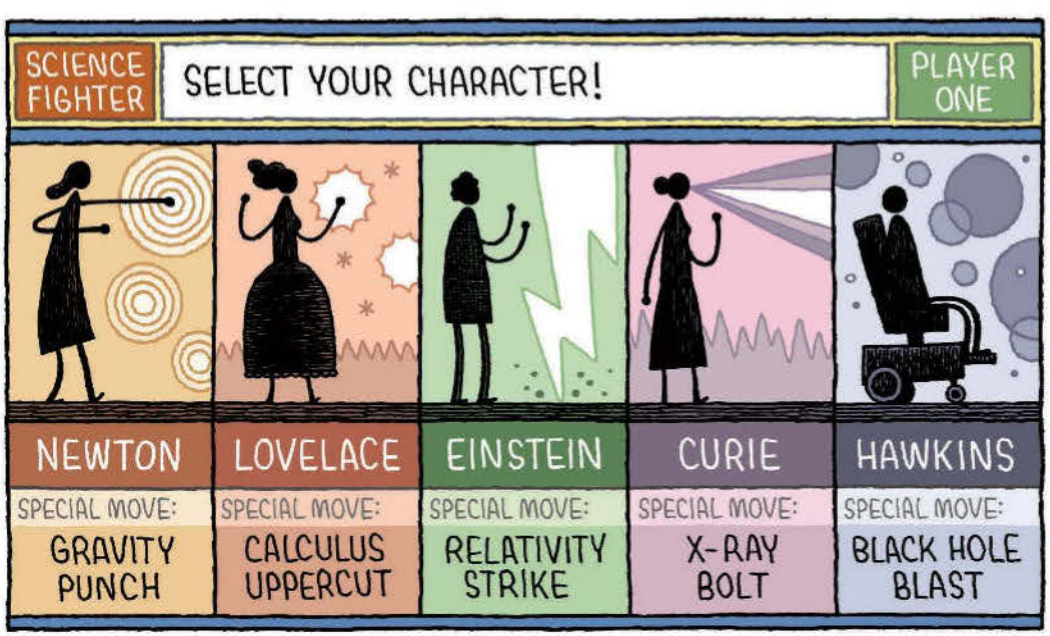
I have noticed, after many years living close to the river Ouse, that floods now tend to be associated with high rainfall: many years ago, they were mostly caused by a thaw of heavy snow in the hills.
Cawood, North Yorkshire, UK

The light fantastic? I did it back in 1968

From Richard Ely
Nicola Jones reports on attempts to communicate data with light (9 January, p 30). What took you so long? My thesis – submitted for a BSc in electrical engineering at the University of Nottingham, UK, in 1968 – was titled *A line-of-sight communication channel based on a light-emitting gallium arsenide diode*. The department had only three diodes with a capacity of 1 ampere. After burning out two I could foresee doom, so I tried pulse amplitude modulation. The transmitter worked a treat.

Incidentally, my thesis referenced a *New Scientist* article titled "Light from semiconductors" (12 December 1963, p 666).
Horton, Northamptonshire, UK

TOM GAULD



For the record

■ **The Zika virus spread to 25 further countries between its arrival in Brazil last year and the time of writing of our report (30 January, p 9).**

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Solving the Equation
started the conversation …

And now we're taking it one step farther. AAUW recently convened meetings with academic and corporate leaders to include their voices in the discussion of women's participation in engineering and computing.

Be the first to know the recommendations that came out of these important events. Visit www.aauw.org/newscientist.

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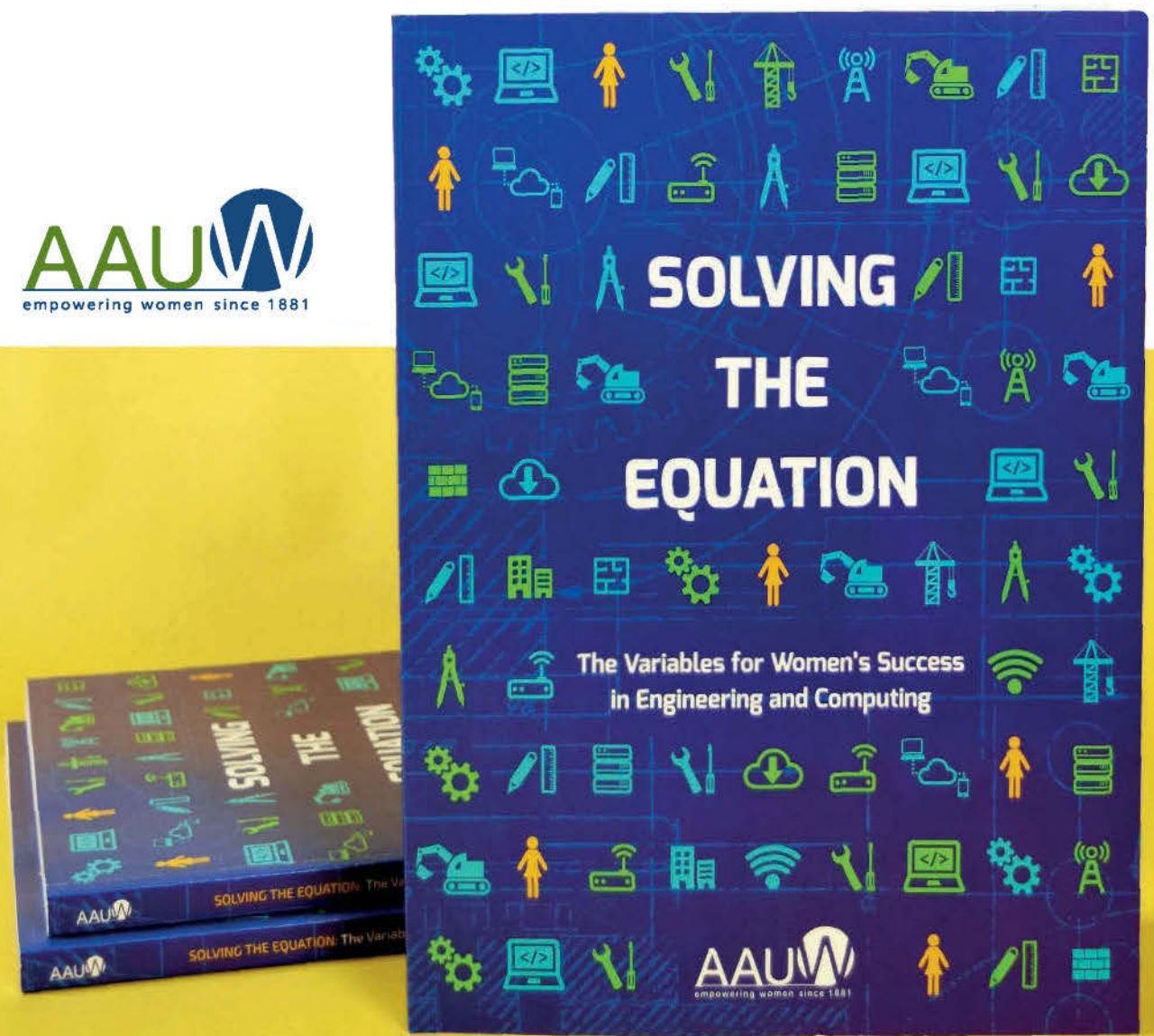

PAUL MCDEVITT

THE aliens have landed – though you would be forgiven for missing them, because these ones are invisible. *Daily Express* journalist Jon Austin ("covering science, nature, and the paranormal") reports the scoop of the century with the news that Ruggero Santilli, CEO of Thunder Energies Corporation, has detected invisible entities using a specially designed telescope – although the results look suspiciously like shaky, out-of-focus blobs of light.

Feedback could spend a page discussing the lifetime output of Santilli, which is rich in both uncorroborated discoveries and unsuccessful lawsuits, but find ourselves distracted by Austin's opus.

In January alone, the *Express* correspondent published news of multiple items discovered on Mars that NASA hasn't publicised, including a totem pole, a fossilised trilobite, a petrified baby, animal bones and more; and clocked up a dozen reports of aliens and UFOs visiting us on Earth.

Most perplexing of all was the revelation that the surface of Mars was actually blue. On this topic, however, even Austin's source – Scott Waring, editor of *UFO Sightings Daily* – "did not go on to explain what the motive for NASA making people think Mars was red instead of blue would be".

LAST week, Feedback discussed strange advice from the BBC to measure snowfall using your dog. Robert Patterson writes to tell us of more dodgy comparisons: *The Times* newspaper reports the discovery of a fossilised crocodile, the 10-metre-long *Machimosaurus rex*, by comparing it in size to a bus, a woman and a light aircraft.

"Apart from the wonderful mix of dimensions, do we yet have a standard size for a woman and a light aircraft?" ponders Robert – neither the woman nor the aircraft were included in the accompanying diagram.

Feedback vaguely recalls their silhouettes cropping up in similar images used for size comparisons, alongside the ubiquitous double-decker bus and waving man. We think someone ought to compile these silhouettes into a single collage – resolving these size questions once and for all.

AN ONLINE pet store had journalists eating out of its hand after unveiling plans for the ultimate pet-lovers' gadget: a collar that translates your dog's barks. The WhatsYapp! pet collar converts woofs into English and delivers them to you by text message anywhere in the world.

Sadly, the stuff of science fiction is, er, science fiction: WhatsYapp! and two other pet gadgets touted by the company exist only in the fertile imaginations of a PR team behind the online pet store. Although the public is encouraged to have their say on which of the three they'd like to see developed into a prototype, the destination web page for this vote is likewise non-existent.

So don't count on chatting to your dog via instant message any time soon. It's probably just as well – Feedback can't imagine yapping pups make good conversationalists.

BEN EVANS is fascinated by recent experiments to demonstrate quantum effects at a macro scale (2 January, p 9) but writes to say he is surprised "as I encounter such quantum effects all the time". He relays a phenomenon as yet uninvestigated by physicists: quantum parking.

"All parking spaces exist in a superposition of being both occupied and unoccupied at the same time," says Ben. "They only collapse into one state or another when observed."

His evidence to support this? "If I attempt to park very near my destination, then all the parking spaces collapse into a state of being occupied. However, if I park further away, when I arrive at my destination on foot at least one of the nearby parking spaces will have collapsed into a state of being unoccupied."

FEEDBACK is reminded of another everyday item that famously exists in superposition until observed: USB cables. Many readers will know that the ubiquitous wires never plug in on the first attempt, requiring you to flip the connector once – often twice – to find the correct one of two possible orientations. Can you think of any others?

THE road to hell is paved with good intentions, and wheelchair users can now find themselves propelled along it at the whim of a remote user. Jiajun Shen and his colleagues have unveiled their concept for "A telepresence wheelchair for elderly people" in a paper published on arxiv.org.

The innovation combines a motorised wheelchair, a remote control system and a telepresence rig that, in principle, allows someone to control the wheelchair while chatting face-to-screen with the person sitting in the chair.

Feedback can't help but ask "what could possibly go wrong?" In an era where there are public

databases of unsecured baby cameras, through which you may watch someone else's children sleep from the comfort of your home, the temptation to follow it up by taking a stranger for a spin in their wheelchair could be too much for some to resist.

"You say Dik Kok is a fitting name for a Dutch urologist," writes Fons VandenBerg. "Only if he were a chef: his name means 'fat cook'"

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Uncommon ancestor

Like other white Europeans I carry about 2.5 per cent Neanderthal genes, more than indigenous Africans. If we all walked out of Africa about 100,000 years ago, what is the explanation for this?

■ We didn't simply walk out of Africa at any particular time. We originated there, and our ancestors sallied forth everywhere, but many genetically distinct populations took various routes over hundreds of thousands of years and their paths repeatedly diverged and converged.

In palaeontological terms, any event that lasts only for millennia is pretty abrupt. Our prehistory back to the estimated origin of agriculture probably spans less than 15,000 years. We are a recent, transient rabble – yet to us, family histories of 1000 years seem ancient.

The Neanderthals were early colonists in Europe, sufficiently distinct from other populations of the genus *Homo* that geneticists can tell them apart. This factor has given us a good idea of when and to what extent Neanderthals merged with their successors. Perhaps hundreds of thousands of years after the Neanderthals, invaders from Africa introduced new genetic material: those that settled in Europe interbred with Neanderthals, so the proportion of such DNA in their descendants is greater than in other populations.

Jon Richfield
Somerset West, South Africa

Aggressive pitch

Why does feedback between a microphone and speaker generate a high-pitched noise, and not a low one?

■ Sounds can be viewed as combinations of sine waves of different frequencies. The Barkhausen stability criterion states that any frequencies that perfectly fit in the system's "distance" (from microphone to speaker and back) and are amplified along the way will be sustained and amplified further.

This distance is hard to pin down because it depends on factors like delays in the electronics, the room's acoustic properties, the positions of the microphones and the resonant frequencies of the instruments and speakers. But higher frequencies are more likely to enter a feedback loop because the waves are shorter. The odds are higher that you can perfectly fit many short waves into a certain distance than many long waves. So although you do get throbbing low-frequency feedback, high-frequency feedback is more likely.

Moving a microphone near a speaker causes feedback because live speakers are never truly silent: close up, you can hear a multi-frequency hum. And as you move the microphone, you're changing the distance and sweeping the range of frequencies that cause feedback, resulting in a high-pitched whine.

Ron Dippold
San Diego, California, US

■ As a musician, I have been a victim of feedback at all points on the frequency spectrum. There are two main reasons why higher frequencies resonate more often. First, most microphones, amplifiers and loudspeakers are designed to be less responsive to lower frequencies than the higher ones of voices and guitars.

Second, lower frequencies need more space to become "in phase" and for their waveforms to flow back and forth. In smaller venues, there is not enough distance between the microphone and speakers for this to happen. Once a stage is large enough, it is more common for bass frequencies to resonate (and for band members to complain about them).

Connor Fitzgerald
Berlin, Germany

Grow your own

If we did not import any food into the UK, how large a population could we sustainably support by producing our own? Fresh water is obviously an important consideration too.

■ If the UK were unable to import any food, the immediate consequence would be a massive market-driven change to a rural economy. The vast majority of British agriculture is devoted to producing meat, whether directly or through cereal crops grown for animal feed. But meat production is notoriously inefficient, typically requiring 10 times as much farmland as vegetables to produce the same amount of food – so meat would become more expensive.

To support our population, we would have to adopt a mainly vegetarian diet, perhaps enlivened by the odd sliver of mass-produced broiler chicken or factory-farmed fish. The countryside would be given over to vegetable production, with enormous acreages of beans, peas and other pulses. The south-east would probably be swathed in polytunnels.

The irony is that if the UK adopted such a diet, people would live longer, healthier lives, leading to short-term population growth. If we also assume further mechanisation, intensive cultivation, cross-breeding, genetic manipulation and whatever extra innovations we come up with, within 30 years we could probably support a population around 10 times the current size – say half a billion people.

A lot of water would be required for vegetable production, but the UK is one of the best-watered countries of its size, with frequent rainfall. The problem is ageing infrastructure that fails to collect and transport enough water from the wet north and west, and instead insists on pumping streams dry to support a rapidly increasing population in the south-east. Reorganising the UK water-supply network would be expensive, but if the alternative was people starving, the money would be found.

Nigel Palmer
London, UK

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